

GRIGNARD REACTIONS *of* **NONMETALLIC SUBSTANCES**

M. S. KHARASCH

*Professor of Chemistry
The University of Chicago*

OTTO REINMUTH

*Research Associate
The University of Chicago*

**NEW YORK
PRENTICE-HALL, INC.**

1954

Copyright, 1954, by Prentice-Hall, Inc., 70 Fifth Avenue, New York. All rights reserved. No part of this book may be reproduced in any form, by mimeograph or any other means, without permission in writing from the publisher.

Library of Congress
Catalog Card Number:

54-7458

PRINTED IN THE UNITED STATES OF AMERICA

Preface

It is reported that Sir William Osler used to open certain of his lectures to medical classes at The Johns Hopkins with the statement that he who knows syphilis knows medicine, for its symptoms can simulate those of any disease in the catalog. With but little more poetic license than the good doctor permitted himself, it might be said that he who knows and understands the Grignard reactions has a fair grasp of organic chemistry, for most fundamental processes have prototypes or analogs in phenomena observable in Grignard systems.

In view of the extent and variety of the subject matter, none but the most arrogantly self-complacent of authors could contemplate the task of summarizing, critically evaluating, and to some extent correlating the labors of a half-century except in a spirit of deep humility and with some sense of inadequacy. In extenuation of our own temerity we (the present authors) plead an intense interest in the subject matter, a fair acquaintance with the literature relating to it, considerable contemplation and some experimental study of its problems, a conviction that the general need of a work of the kind here presented has been great and continues to grow, and a belief that no one better qualified for the task seems at all likely to undertake it.

Early in our exploratory compilations of data and attempts at organization of subject matter we discovered that no exhaustive treatise (even if it were achievable with the facilities at our command) could be confined to a one-volume work producible at a cost within the means of the average prospective individual purchaser. Reluctantly but resolutely, therefore, we excluded from our plans consideration of the reactions of Grignard reagents with other metallic compounds, as well as consideration of the Grignard reagents other than those which behave as though the magnesium were directly linked to carbon.

54/55- As the work progressed, the necessity for further selection within the field thus delimited became apparent. Historical resumé's have been relentlessly condensed; hypotheses that seem to have had no survival value have received no more than bare mention, and have in some cases been ignored altogether. Reports that we regard as trivial or grossly inaccurate have been relegated to merciful obscurity, and mention of articles, however interesting or significant, that did not fit into the outline finally adopted has been omitted.

In a work of this scope it is scarcely conceivable that there have been no errors of judgment in evaluation of periodical reports; probably there

have been omissions by reason of oversight. Regarding these we solicit the reader's indulgence, and invite his correction.

The time-element, also, has imposed certain limitations upon the present work. In general, the major tabulations of data do not extend beyond the material covered by *Chemical Abstracts* of June, 1950. Insofar as possible we have attempted to include in the book discussion of, or at least reference to, theoretically significant articles and relevant reviews up to the time of going to press. When it has been possible to do so in manuscript we have incorporated additional data so disclosed in the appropriate tabulations.

After the Introduction and the group of chapters (II-V) dealing with the preparations and properties of the Grignard reagents, division of subject matter into chapters has been made on the basis of co-reactants, or groups of closely related co-reactants. The exact sequence of chapters adopted has no fundamental significance so far as we are aware. On the whole it seemed expedient to give high priority to reactions of great general interest (as indicated by the volume of relevant material), and to those of greatest theoretical maturity. This may serve as explanation of the fact that certain blocs of chapters which the reader might be inclined to regard as closely related have been broken by interpolations.

In the interests of space conservation any completely developed theoretical concept in one chapter is referred to in other chapters to the subject matter of which it is pertinent. Of relatively few chapters, therefore can it be said that they are complete and independent expositions of the subject matter that they purport to treat.

The method of presentation necessarily varies somewhat from chapter to chapter, depending upon the quantity, quality, and theoretical significance of the relevant data available. Whenever possible a chapter content includes: a brief historical resumé, a definition of the so-called "normal" reaction (or reactions) and some consideration of probable mechanisms, descriptions of some exemplary preparative procedures, definitions and theoretical discussions of various so-called "abnormal" reactions, and a tabulation (or tabulations) of literature data. Chapter VI (Aldehydes and Ketones) perhaps best exemplifies the "full treatment."

Despite the chastenings of experience we have not hesitated to propose working hypotheses, or to theorize speculatively, whenever it seemed to us that to do so might prove constructive. We regard as constructive such hypotheses and theories as serve to interrelate otherwise isolated phenomena, or as embody implications that suggest profitable lines of experimental investigation.

As regards some segments of the field, a more confident and a more confidence-inspiring effort at generalization and co-ordination may be attempted when the "factual" foundation has been more firmly established. In so far as the relatively rapid, essentially ionic, addition re-

actions are concerned, the qualitative facts may generally be taken to be substantially as reported and generally accepted. In oxidation-reduction reactions (especially those involving "non-reducing" Grignard reagents), however, the "facts" for Grignard reagents prepared from ordinary magnesium may be quite different from those for reagents prepared from sublimed magnesium of high purity. In some cases we have been able to cite experimental evidence to this effect, in others we have voiced our misgivings, and in yet others we have left it to the discernment of the reader to recognize areas of uncertainty in "factual" data.

Although we have exercised all due diligence, we are fully aware that the major tabulations of data are by no means exhaustive. No method of literature indexing at present in use would serve to discover all Grignard reactions reported. Perhaps half the entries in these tabulations have been located through references in articles to which we were directed by literature abstracts. Almost daily, up to the time of going to press, we have discovered new sources of data, and have made new interpolations in the tables. Nevertheless, we are reasonably confident that the tabulations are *comprehensive* in the sense that no significant reported phenomenon has escaped notice.

Throughout the planning and execution of this work the authors have borne in mind the imperative that information must be easily and quickly accessible to the user who employs it primarily as a ready reference compendium. The table of contents is, we hope, adapted to this end. In preparation of the General Index every effort has been made to anticipate the reader's point of view in the selection of key topics. To avoid the imposition of an unbearable burden upon the General Index, tabulations of data, insofar as possible, are self-indexed.

For example, most major tabulations of Grignard reactions are self-indexed according to the empirical formulae of the Grignard co-reactants. Conventional orderings of symbols in empirical formulae have been somewhat modified to suit individual cases. In general the ordering of symbols is: carbon; hydrogen; characteristic element (or elements), other than carbon and hydrogen, of the functional group; all other elements in alphabetical order. The ordering of the esters ($\text{RCO}_2\text{R}'$) is based primarily upon the empirical formulae of the acid anions (RCO_2^-), and secondarily upon the empirical formulae of the radicals (R') of the alcohols ($\text{R}'\text{OH}$). The ordering of the amides ($\text{RCONR}'\text{R}''$) is based primarily upon the empirical formulae of the acyl radicals (RCO), and secondarily upon the empirical formulae of the amido radicals ($\text{NR}'\text{R}''$). The ordering of the acyl halides (RCOX) is similarly based primarily upon the empirical formulae of the acyl radicals (RCO), and secondarily upon the halogen (X) present. Functional halogens (as in RX , RCOX , RMgX) are arranged in the order: Cl, Br, I. Non-functional halogens take their places in the conventional alphabetical ordering. For a given co-reactant, the Grignard reagents are ordered in accord with the principles outlined.

In general, although some exceptions have been made, polyfunctional Grignard co-reactants with one functional group reacting appear in one table only; those with more than one functional group reacting appear in more than one table.

Because the method of arrangement and indexing adopted provides no ready means for location of information relating to individual Grignard reagents, we have felt it obligatory to include, as an appendix, an Index of Grignard Reagents. With respect to a given Grignard reagent, this appendix undertakes to answer for the reader four questions. (1) Has preparation of the reagent been reported? (2) Is there a detailed description, or reference to a detailed description, of its preparation in the text? (3) Is there textual mention of unique or significant properties of the reagent? (4) With what types of co-reactants has the reagent been treated?

In the preparation of certain portions of our manuscript we have had the benefit of consultation with several of our colleagues whose information, advice, and criticism we gratefully acknowledge. In this respect we are especially indebted to: Dr. Walter Nudenberg, Dr. Wilbert H. Urry, Dr. G. Willard Wheland, and Dr. Frank H. Westheimer. We, our publishers, and their printers also owe an irreparable debt of gratitude to Mrs. Eleanor Saluski, whose indefatigable and ever-cheerful labors produced a typescript of unsurpassed cleanliness and accuracy.

M. S. KHARASCH
OTTO REINMUTH

Contents

I. HISTORICAL INTRODUCTION.....	1
II. THE PREPARATION OF GRIGNARD REAGENTS	5
Quality and Quantity of Magnesium	6
Activators and Inhibitors	8
Purity of Halide.....	16
Relative Quantity of Ether.....	16
Rate of Addition of Halide	18
Agitation of the Reaction Mixture	19
Relative Reactivities of Halides	20
Some Illustrative Preparations in the Classical Manner ..	22
<i>Apparatus</i>	22
The "cyclic reactor"	23
<i>Reagents</i>	24
<i>General method for preparation of organomagnesium</i> <i>halides</i>	25
<i>Methylmagnesium chloride</i>	25
<i>Ethylmagnesium chloride</i>	26
<i>General method for preparation of alkylmagnesium</i> <i>chlorides</i>	26
<i>Tertiary alkylmagnesium chlorides</i>	26
<i>Allylmagnesium chloride</i>	27
<i>β-Methallylmagnesium chloride</i>	28
<i>Cyclohexylmagnesium chloride</i>	28
<i>Cinnamylmagnesium chloride</i>	28
✓ <i>Phenylmagnesium bromide</i>	28
<i>Mesitylmagnesium bromide</i>	29
<i>9-Phenanthrylmagnesium bromide</i>	29
<i>9-Anthrylmagnesium bromide</i>	29
<i>Styrylmagnesium bromide</i>	29
<i>Triphenylmethylmagnesium bromide</i>	31
<i>Other Grignard reagent preparations (T. II-VI)</i>	31
<i>Relative yields of RMgX (T. II-VII)</i>	32
Some Limitations of the Classical Method	32
Grignard Reagent Preparation by "Entrainment"	38
<i>Some representative preparations (T. II-VIII)</i>	41
Preparation of Grignard Reagents in Solvents Other than Ethyl Ether.....	45
<i>Ethers other than ethyl ether</i>	45

II. THE PREPARATION OF GRIGNARD REAGENTS (*Cont'd*)Preparation of Grignard Reagents in Solvents Other than Ethyl Ether (*Cont'd*)

Tertiary amines 49

Hydrocarbons 50

Preparation of Grignard Reagents without Solvent (Other than Excess Halide) 53

Mechanism and Kinetics of Grignard Reagent Formation . 56

A proposed reaction scheme 61

The Wurtz and disproportionation reactions 63

Reactions involving the solvent 63

Hydrogen Displacement Methods of Grignard Reagent Preparation..... 66

Acetylenic hydrocarbons 66

Non-acetylenic hydrocarbons and their derivatives 71

Cyclopentadiene, indene, and fluorene 71

Phenylacetic acid 72

Sulfones 73

Aromatic ethers 74

2-Methylbenzothiazole 74

Thiophene 75

Nitrogen heterocycles with "active" hydrogen 75

Pyrroles 75

Indoles 81

Imidazole 84

Pyrazole 85

Carbazole 86

Grignard Reagents from Free Radicals..... 86

Addition of Grignard Reagents to Olefins 87

Grignard Reagents from Organolithium Compounds 90

Grignard Reagents from Organomercuri Compounds 90

Grignard Reagents from Alkyl Sulfates 90

III. ESTIMATION AND DETECTION OF GRIGNARD REAGENTS 92

Estimation 92

Detection 95

IV. CONSTITUTION AND DISSOCIATION OF GRIGNARD REAGENTS 99

Solvent Association 99

Grignard Reagent Association..... 102

The Schlenk Equilibrium 104

Electrolytic Properties of Grignard Reagent Solutions ... 109

Ionization of Grignard reagents 110

Electrolytic discharge of ions..... 112

IV. CONSTITUTION AND DISSOCIATION OF GRIGNARD REAGENTS (*Cont'd*)

Non-ionic Dissociation of Grignard Reagents.....	114
--	-----

V. SOME RADICAL REACTIONS OF GRIGNARD REAGENTS. 116

Homolytic Dissociation	116
Action of Some Metallic Halides on Grignard Reagents ..	117
<i>Unstable intermediate organometallic compounds</i>	118
<i>Reactions of Group VIII (Fe, Co, Ni) halides</i>	119
Some Reactions Induced by Cobaltous Halides	122
<i>Behavior of free radicals in solution</i>	124
<i>Coupling of acyl radicals</i>	126
<i>Metallic subhalide reduction of ketones</i>	127
<i>Hydrogen cleavage of ethers</i>	128
<i>Reductions of ω-haloalkyl phenyl ethers</i>	128
<i>Functional exchange</i>	130
Uncatalyzed "Coupling" Reactions.....	131
Some Reactions of Group IB and Group VIII Halides (T. V-I)	133

VI. REACTIONS OF GRIGNARD REAGENTS WITH ALDEHYDES, KETONES, AND KETENES 138

The "Normal" Addition Reactions.....	138
Preparative Procedures	143
Grignard Reductions of Aldehydes and Ketones.....	147
<i>Reduction by the Grignard reagent</i>	147
<i>Possibility of suppressing Grignard reagent reduction</i> ..	157
<i>Alkoxide reduction</i>	158
<i>Magnesium halide reduction</i>	160
Enolate Formation by Grignard Reagents	166
<i>Probable mechanism of Grignard reagent enolate formation</i>	174
Grignard Condensations of Aldehydes and Ketones.....	176
α -Halo Ketones and Aldehydes.....	181
<i>"Normal" addition</i>	182
<i>Halogen-radical exchange</i>	182
<i>Dehalogenation (reductive enolization)</i>	189
Probable mechanism of α -halo ketone dehalogenation	193
Grignard Reagent Addition to Conjugated Carbonyl Systems.....	196
<i>Facilitation of 1,4- at expense of 1,2-addition</i>	219
<i>Possibility of suppressing 1,2-addition</i>	221
<i>Probable mechanism of 1,4-addition</i>	221
<i>Possible suppression of 1,4- in favor of 1,2-addition</i> ..	223
<i>Constitutional factors affecting order of addition</i>	224

VI. REACTIONS OF GRIGNARD REAGENTS WITH ALDEHYDES, KETONES, AND KETENES (*Cont'd*)

Grignard Reagent Addition to Conjugated Carbonyl Systems (*Cont'd*)

<i>Cleavage reactions involving 1,4-addition</i>	231
<i>1,6- (or "Transannular 1,4-") addition</i>	234
<i>Cleavages involving 1,6-addition</i>	238
Ketenes	238
Aldehydes (T. VI-XVII)	240
Ketones (Acyclic) and Ketenes (T. VI-XVIII)	310
Ketones (Cyclic) (T. VI-XIX)	453

VII. REACTIONS OF GRIGNARD REAGENTS WITH QUINONES 529

Quinones (T. VII-II)	535
----------------------------	-----

VIII. REACTIONS OF GRIGNARD REAGENTS WITH ESTERS AND LACTONES. 549

"Normal" Addition to Carboxylic Esters	549
<i>Probable mechanisms of carboxylic ester reactions</i> ...	553
Relative Reactivities of Carboxylic Esters	554
Preparative Procedures	557
<i>Carboxylic esters of the type RCO_2R'</i>	557
The Barbier-Wieland degradation	557
<i>Other esters</i>	560
Ketone (or Aldehyde) Formation	561
Reduction	562
Grignard Reagent Addition to α,β -Unsaturated Carboxylic Esters	563
Claisen (Acetoacetic Ester-Type) Condensations	564
<i>Symmetrical ketone formation (R_2CO from $2 RCO_2R'$)</i> ..	566
Ester Cleavages	567
<i>"Hindered" alkyl esters</i>	567
<i>"Hindered" aryl esters</i>	572
Miscellaneous Byproducts of Ester Reactions	572
Reactions of Grignard Reagents with Lactones	574
Esters (T. VIII-III)	579
Lactones (T. VIII-IV)	688

IX. REACTIONS OF GRIGNARD REAGENTS WITH CARBONYL HALIDES 709

Speculations on the ("Normal") Reaction Mechanism....	709
Preparation of Ketones by Grignard-Halide Interaction...	712
Ketone Preparation with the Aid of Zinc and Cadmium Salts	713
Ketones from Acid Halides (T. IX-I)	716
Reduction of Acid Halides by Grignard Reagents	725

IX. REACTIONS OF GRIGNARD REAGENTS WITH CARBONYL HALIDES (*Cont'd*)

Ester Formation through Ether Cleavage	727
Coupling	727
Hexaarylethane Formation	729
Ketone Enolization and C-Acylation	729
Other "Abnormal" Reactions	730
α -Halo Carbonyl Halides	731
α,β -Unsaturated Carbonyl Halides	732
Carbonyl Halides Other than Those of the Type RCOX ..	733
Carbonyl Halides (T. IX-II)	734

X. REACTIONS OF GRIGNARD REAGENTS WITH NITRILES AND OTHER CYANO COMPOUNDS

767

The "Normal" Reaction and Its Probable Mechanism....	767
Preparative Procedures	769
<i>t</i> -Alkylamine (or Tertiary Alcohol) Formation.....	772
Keteniminate Formation	773
<i>Amide formation</i>	774
<i>Condensation and polymerization</i>	774
Cyano Group Displacement	776
<i>Replacement by organic radical of Grignard reagent</i> ...	776
<i>Coupling</i>	778
<i>Reductive displacement</i>	779
α,β -Unsaturated Nitriles	782
Cyanohydrins	783
α -Halo Nitriles	784
Cyanogen	785
Cyanogen Halides	787
Cyanamides	788
Cyano Compounds (T. X-I).....	789

XI. REACTIONS OF GRIGNARD REAGENTS WITH CARBOXYLIC ANHYDRIDES

846

The "Normal" Reactions	846
Speculations Concerning Reaction Mechanisms	849
Preparative Procedures	851
Carboxylic Anhydrides (T. XI-I)	852

XII. REACTIONS OF GRIGNARD REAGENTS WITH CARBOXYLIC AMIDES, IMIDES, AND LACTAMS.....

870

Ketone or Aldehyde Formation (from Amides).....	870
Nitrile Formation (from Amides)	870
Amine Formation (from Amides)	871
Imine Formation (from Amides)	872

XII. REACTIONS OF GRIGNARD REAGENTS WITH CARBOXYLIC AMIDES, IMIDES, AND LACTAMS (*Cont'd*)

Phthalide Formation	873
α -Halo Amides	873
α,β -Unsaturated Amides	875
Amide Condensations	875
Unreactive Amides	876
Imides	876
Lactams	878
Amides, etc. (T. XII-I)	880

XIII. REACTIONS OF GRIGNARD REAGENTS WITH OXIDES OF CARBON, AND WITH CARBOXYLIC ACIDS AND THEIR SALTS

909

Carbon Suboxide	909
Carbon Monoxide	910
Carbon Dioxide	913
<i>Preparative procedures</i>	914
(T. XIII-I)	915
<i>Miscellaneous uses of carbonation reaction</i>	947
Carboxylic Acids and Their Salts	948
(T. XIII-II)	951

XIV. REACTIONS OF GRIGNARD REAGENTS WITH EPOXIDES


961

Ethylene Oxide	961
Epoxide Isomerization	965
Factors Influencing Direction of Ring-Opening	967
<i>Ring-opening in isomerizations</i>	968
<i>Ring-opening in additions</i>	973
1,4-Addition	975
Preparative Procedures	976
Epoxides (T. XIV-I)	978

XV. REACTIONS OF GRIGNARD REAGENTS WITH ETHERS, ACETALS, AND KETALS

1013

Cleavages of Acyclic Ethers	1013
<i>Speculations on the mechanism of ether cleavage</i>	1022
Reductive (Free-Radical) Cleavage of Ethers	1025
Preparative Procedures	1029
Cleavages of Cyclic Ethers	1031
Thio and Seleno Ethers	1035
Anomalous Ether Cleavages	1036
Grignard Reagents from Ethers	1040
Acetals and Ketals	1041

XVI. REACTIONS OF GRIGNARD REAGENTS WITH ALKYL, ARALKYL, AND CYCLOALKYL HALIDES	1046
Early Studies	1046
Speculations Concerning Reaction Mechanisms	1048
<i>The "normal" reaction</i>	1048
<i>Dehydrohalogenation and dehalogenation</i>	1052
Condensations with Acetylenic Grignard Reagents	1053
"Coupling" Reactions	1054
Induced "Coupling" Reactions	1056
"Forced" Reactions	1059
Functional Exchange	1060
The Halohydrins	1064
Alkyl Halides (T. XVI-I)	1067
XVII. ALLYLIC REARRANGEMENTS IN GRIGNARD REACTIONS	1133
"Abnormal" Reactions of Arylmethylmagnesium Halides .	1133
"Abnormal" Reactions of Substituted Allylmagnesium Halides	1145
<i>Recapitulation</i>	1156
Reactions of Grignard Reagents with Allylic Co-reactants	1157
<i>Allylic halides</i>	1157
<i>Butenyl esters</i>	1158
XVIII. THE TSCHUGAEFF-ZEREWITINOFF METHOD FOR THE DETERMINATION OF "ACTIVE" HYDROGEN ..	1166
The "Grignard Machine"	1169
"Active" Hydrogen Groups	1169
Sources of Error, and Limitations of the Method	1171
Applications of the Method	1173
"Active" Hydrogen (T. XVIII-I)	1175
XIX. REACTIONS OF GRIGNARD REAGENTS WITH MISCELLANEOUS NITROGEN COMPOUNDS.....	1199
Isocyanates and Isothiocyanates	1199
Compounds Containing the Grouping $\text{—N}=\text{C}$ 	1204
<i>Aldimines</i>	1204
<i>Ketimines</i>	1208
<i>Aldazines</i>	1211
<i>Hydramides</i>	1212
<i>Carbodiimides</i>	1213
<i>Phenylhydrazones and osazones</i>	1213
<i>Oximes and isonitroso compounds</i>	1217
<i>Semicarbazones</i>	1222
Diazo Compounds	1223

XIX. REACTIONS OF GRIGNARD REAGENTS WITH MISCELLANEOUS NITROGEN COMPOUNDS (*Cont'd*)

Azides.....	1226
Nitroso Compounds.....	1228
<i>N</i> -Nitrosoamines.....	1229
Azoxy Compounds, Furoxans, Amine Oxides, and Nitrile Oxides.....	1232
Hydroxylamines and Alkoxyamines.....	1235
Nitro Compounds.....	1237
Nitrites and Nitrates.....	1242
<i>N</i> -Haloamines and <i>N</i> -Haloimines.....	1243
Azo Compounds.....	1249
Quaternary Salts.....	1251
Ammonia, Amines, Hydrazines, and Triazenes.....	1255
Cyanamides.....	1260
Isonitriles (Carbylamines).....	1260
Miscellaneous Unclassified Nitrogen Compounds.....	1260

XX. REACTIONS OF GRIGNARD REAGENTS WITH OXYGEN, SULFUR, SELENIUM, AND TELLURIUM..... 1264

Oxygen.....	1264
Chemiluminescence.....	1273
Sulfur.....	1274
Selenium.....	1276
Tellurium.....	1276

XXI. REACTIONS OF GRIGNARD REAGENTS WITH MISCELLANEOUS SULFUR, SELENIUM, AND TELLURIUM COMPOUNDS..... 1277

Alkyl Sulfates.....	1277
Sulfonic Esters.....	1278
Esters of Other Sulfur Acids.....	1285
<i>Sulfites</i>	1285
<i>Sulfinates</i>	1285
<i>Sulfenates</i>	1285
<i>Thiolsulfonates</i>	1286
<i>Thiocarboxylates</i>	1286
Carbon Disulfide and Carbonyl Sulfide.....	1286
Sulfur Dioxide.....	1288
Acid Halides.....	1290
<i>Sulfonyl halides</i>	1290
<i>Thionyl and sulfuryl chlorides</i>	1294
<i>Chlorosulfonates</i>	1295
Sulfur Chlorides.....	1295
Sulfoxides.....	1296

XXI. REACTIONS OF GRIGNARD REAGENTS WITH MISCELLANEOUS SULFUR, SELENIUM, AND TELLURIUM COMPOUNDS (*Cont'd*)

Sulfones	1297
Thioketones (Thiones)	1299
Miscellaneous Unclassified Sulfur Compounds	1300
Selenium Compounds	1302
Tellurium Compounds	1303

XXII. REACTIONS OF GRIGNARD REAGENTS WITH SILICON COMPOUNDS 1306

Silicon Halides	1306
Silicon Esters	1307
Some Illustrative Preparations	1308
<i>Ethyltrichlorosilane from silicon tetrachloride</i>	1308
<i>Dichlorodiethylsilane from silicon tetrachloride</i>	1308
<i>Fluorotri-n-amylosilane from silicon tetrafluoride</i>	1308
<i>Tetraethylsilane from silicon tetrachloride</i>	1308
<i>Tetraphenylsilane from silicon tetrachloride</i>	1308
<i>Triethylsilane from trichlorosilane</i>	1309
<i>Hexaethylidisiloxane from ethyl orthosilicate</i>	1309
Silicon Compounds (T. XXII-I)	1310

XXIII. REACTIONS OF GRIGNARD REAGENTS WITH MISCELLANEOUS NON-METALLIC SUBSTANCES 1332

Halogens	1332
Boron Compounds	1335
Phosphorus Compounds	1335
<i>Phosphines</i>	1335
<i>Phosphorus trichloride</i>	1335
<i>Monochloro and dichloro phosphine derivatives</i>	1337
<i>Phosphorus pentachloride</i>	1338
<i>Phosphoryl chloride (POCl₃)</i>	1338
<i>Phosphoric and phosphorous esters</i>	1339
<i>Phosphorus sulfides</i>	1340
<i>Phosphorus compounds (T. XXIII-III)</i>	1340

INDEX OF GRIGNARD REAGENTS..... 1347

GENERAL INDEX..... 1363

Tables

II-I. Yields (%) of organomagnesium halides from magnesium, magnesium-copper alloy, and iodine-activated magnesium-copper alloy	13
II-II. Effects of ether dilution of halide on Grignard reagent yields	17
II-III. Effect of rate of halide addition on Grignard reagent yields	19
II-IV. Relative reactivities of halide pairs toward magnesium ..	21
II-V. Relative reactivities of halides toward magnesium	22
II-VI. Some Grignard reagent preparations in the classical manner.....	30
II-VII. Relative yields of some normal and iso alkylmagnesium halides	32
II-VIII. Some representative Grignard reagent preparations by the method of "entrainment"	41
II-IX. Preparation of Grignard reagents in <i>n</i> -butyl ether	47
II-X. Preparation of Grignard reagents in 4-methyl-1, 3-dioxane	49
II-XI. Reaction of magnesium with alkyl halides in benzene....	52
II-XII. Preparations of several Grignard reagents in hydrocarbon solvents with the aid of dimethylaniline	53
III-I. Sensitivity of the Michler's ketone test for phenylmagnesium bromide in the presence of benzaldehyde.....	97
IV-I. Disproportionation equilibria (?) of Grignard reagents in ethyl ether solution.....	105
V-I. Some reactions of Group IB and Group VIII halides with Grignard reagents	133
VI-I. Some illustrative preparative reactions of Grignard reagents with aldehydes and ketones	145
VI-II. Reduction of benzophenone by alkylmagnesium halides ..	153
VI-III. Reduction of unsymmetrical ketones with isobornylmagnesium chloride	155
VI-IV. Rate of enolization of camphor by methylmagnesium iodide in ethyl ether solution at 20°	167

VI-V. Effect of solvent and of nature of Grignard reagent upon rate of enolization of camphor at room temperature	168
VI-VI. Enolization of pulegone by various non-reducing Grignard reagents in ethyl ether at 40°	168
VI-VII. Reaction of methylmagnesium iodide with various ketones in isoamyl ether (quantities in millimoles)	169
VI-VIII. Reactions of <i>n</i> -propyl- and isopropylmagnesium bromides with various <i>n</i> -propyl and isopropyl ketones	170
VI-IX. Reactions of various Grignard reagents with diisopropyl ketone	170
VI-X. Competitive enolization and addition reactions of methylmagnesium halides with ketones	171
VI-XI. Competitive enolization and addition reactions of methylmagnesium iodide with several acetyl and diacetyl methylated benzenes	172
VI-XII. Enol content of several ketones as estimated by C_2H_5ZnI reaction	172
VI-XIII. Enol content of several ketones as estimated by Meyer's bromination method	173
VI-XIV. Enol content of several ketones as estimated by Schwarzenbach's modification of Meyer's bromination method .	173
VI-XV. Ketolization through the agency of Grignard reagents	179
VI-XVI. Addition of Grignard reagents to conjugated carbonyl systems of the type $RCOCR^1=CR^2R^3$	198
VI-XVII. Reactions of Grignard reagents with aldehydes	240
VI-XVIII. Reactions of Grignard reagents with ketenes and acyclic ketones	310
VI-XIX. Reactions of Grignard reagents with cyclic ketones	453
VII-I. Products of the treatment of 5,12-diphenyl-5,12-dihydro-5,12-naphthacenediol with various reagents	531
VII-II. Reactions of Grignard reagents with quinones	535
VIII-I. Relative amounts of gases liberated in the reactions of certain alkylmagnesium halides with certain aliphatic esters and with the respective ketones corresponding to the first stage of ester addition	552
VIII-II. Some illustrative preparative reactions of Grignard reagents with carboxylic, carbonic, and ortho esters	558
VIII-III. Reactions of Grignard reagents with carboxylic, orthoformic, carbonic, and orthocarbonic esters	579

VIII-IV. Reactions of Grignard reagents with lactones and lactides	688
IX-I. Preparation of ketones from acid halides with the aid of cadmium or zinc salts.....	716
IX-II. Reactions of Grignard reagents with carbonyl halides ...	734
X-I. Reactions of Grignard reagents with cyano compounds...	789
XI-I. Reactions of Grignard reagents with carboxylic anhydrides	852
XII-I. Reactions of Grignard reagents with amides, imides, and lactams	880
XIII-I. Reactions of Grignard reagents with carbon dioxide	915
XIII-II. Reactions of Grignard reagents with carboxylic acids and their salts.....	951
XIV-I. Reactions of Grignard reagents with epoxides	978
XV-I. Reactions of Grignard reagents ($R''MgX$) with acyclic ethers (ROR')	1017
XV-II. Reactions of ethers (1 mole) with ethyl ethereal Grignard reagent solutions in the presence of metallic halides at or near room temperature	1027
XV-III. Reactions of some Grignard reagents with trimethylene oxide	1032
XV-IV. Reactions of Grignard reagents ($R'''MgX$) with acetals $[RCH(OR'')]_2$ and ketals $[RR'C(OR'')]_2$	1042
XVI-I. Reactions of Grignard reagents with alkyl, aralkyl, and cycloalkyl halides.....	1067
XVII-I. Some reactions of benzyl Grignard reagents and their analogs	1134
XVII-II. Some reactions of butenyl Grignard reagents	1149
XVII-III. Butenes from the reaction of butenylmagnesium bromide with "active hydrogen" compounds	1152
XVII-IV. Reactions of Grignard reagents with allylic halides	1159
XVIII-I. Results of determinations of apparent "active" hydrogen content by the Tschugaeff-Zerewitinoff method	1175
XIX-I. "Normal" reactions of Grignard reagents with isocyanates and isothiocyanates	1201
XIX-II. Reactions of Grignard reagents with methyleneimines of the type $R'N=CHR''$ (aldimines)	1205
XIX-III. Triazene (RN_3HR') formation by reaction of azides (RN_3) with Grignard reagents ($R'MgX$).....	1227

XIX-IV. Reactions of nitroso compounds with Grignard reagents ..	1230
XIX-V. Reduction of azoxy compounds by Grignard reagents	1232
XIX-VI. Reactions of alkoxyamines with Grignard reagents	1236
XIX-VII. Reactions of aryl nitro compounds with arylmagnesium halides	1239
XIX-VIII. Some reactions of Grignard reagents with α -nitro olefins .	1241
XIX-IX. Reactions of monochloroamine with Grignard reagents....	1244
XIX-X. Reactions of monochloroamine with RMgX and R_2Mg	1245
XIX-XI. Reactions of various <i>N</i> -monochloro- and <i>N,N</i> -dichloro- alkylamines with Grignard reagents	1246
XIX-XII. Reactions of nitrogen trichloride with Grignard reagents .	1247
XIX-XIII. Reactions of monobromoamine with Grignard reagents ...	1248
XIX-XIV. Reactions of dibromoamine with Grignard reagents	1248
XIX-XV. Reactions of <i>N</i> -chloroimines with Grignard reagents	1248
XX-I. Preparation of alkyl hydroperoxides by slow addition of ethereal RMgX solution (50 ml.) to O_2 -saturated Et_2O (50 ml.)	1267
XX-II. The oxygen-oxidation of Grignard reagents	1268
XXI-I. Reactions of Grignard reagents with symmetrical alkyl sulfates	1279
XXI-II. Reactions of Grignard reagents with alkyl esters of aryl- sulfonic acids	1282
XXI-III. Reactions of Grignard reagents with alkanesulfonic esters and aryl <i>p</i> -toluenesulfonates	1284
XXI-IV. Reactions of Grignard reagents with carbon disulfide	1287
XXI-V. Reactions of Grignard reagents with sulfur dioxide	1289
XXI-VI. Reactions of Grignard reagents with sulfonyl halides	1292
XXI-VII. Reactions of Grignard reagents with sulfonyl chloride ...	1295
XXI-VIII. Reactions of Grignard reagents with tellurium compounds	1304
XXII-I. Reactions of Grignard reagents with silicon compounds ..	1310
XXIII-I. Reactions of Grignard reagents with halogens	1333
XXIII-II. Reactions of Grignard reagents with boron compounds ...	1336
XXIII-III. Reactions of Grignard reagents with phosphorus com- pounds	1340

GRIGNARD REACTIONS
of
NONMETALLIC SUBSTANCES

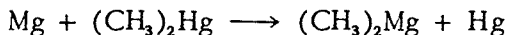
CHAPTER I

Historical Introduction¹

The preparation of organomagnesium compounds antedated that of the Grignard reagents (organomagnesium halides) by some forty years. Hallwachs and Schafarik² produced at least traces of diethylmagnesium by heating ethyl iodide with magnesium particles in a sealed tube. Although they did not isolate the compound, they noted its reactivity toward atmospheric oxygen and water.

Cahours³ reported the production of dimethylmagnesium and diethylmagnesium in a similar manner, and described the preparation and isolation of the latter. The description of the compound as a liquid and the analytical data recorded indicate considerable contamination with residual ethyl iodide. The material was, however, sufficiently pure to exhibit the spontaneous inflammability in air characteristic of it.

Löhr⁴ prepared dimethyl-, diethyl- and dipropylmagnesium by action of the respective iodides on magnesium, and correctly described the substances as solids. In order to decide the question whether the solid residue remaining after the distillation of excess methyl iodide consists of methylmagnesium iodide or a mixture of dimethylmagnesium and magnesium iodide, Löhr prepared the organomagnesium compound by a method that admitted the presence of no iodides, namely,



and concluded that the organic product of the reaction of methyl iodide with magnesium (in addition to gaseous hydrocarbon) is dimethylmagnesium.

¹See also: "Les Prix Nobel en 1912," P. A. Norstedt & Soner, Stockholm, 1913, pp. 18-24, 56-9; Schmidlin, *Chem.-Ztg.*, 36, 1449-51 (1912); "Notice sur la vie et les travaux de Victor Grignard," Courtot, *Bull. soc. chim.*, [5], 3, 433-72 (1936); "Victor Grignard," Gilman, *Proc. Am. Chem. Soc.*, 59, 17-19 (1937); "Genèse et évolution de la découverte des composés organo-magnésiens mixtes," Locquin, *Bull. soc. chim.*, [5], 17, 896-906 (1950); "Commémoration du cinquantième de la réaction de Victor Grignard," Karrer, *Bull. soc. chim.*, [5], 17, 907-9 (1950); "Historique et aspects particuliers de la réaction de Victor Grignard," Colonge, *Bull. soc. chim.*, [5], 17, 910-8 (1950); "Fifty years of the Grignard reaction," Rheinboldt, *J. Chem. Education*, 27, 476-88 (1950).

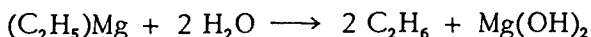
²Hallwachs and Schafarik, *Ann.*, 109, 206-9 (1859).

³Cahours, *Ann. chim.*, [3], 58, 5-82 (1860); *Ann.*, 114, 227-55 (1860).

⁴Löhr, *Ann.*, 261, 48-87 (1891).

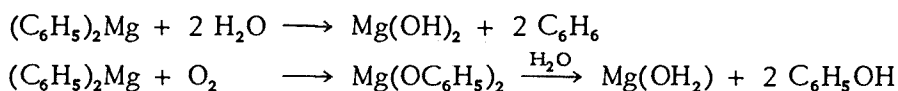
He noted the solubility of the organomagnesium compounds in dry benzene and ether, confirmed their violent reactivity toward water, and remarked their inflammability, not only in air and oxygen, but in carbon dioxide.

Hermann Fleck⁵ of Philadelphia, continuing the researches of Löhr in the laboratory of Lothar Meyer at the University of Tübingen, prepared dimethyl- and diethylmagnesium from magnesium amalgam and the respective alkyl iodides, and further investigated their properties. He showed that the reaction between diethylmagnesium and water may be represented as

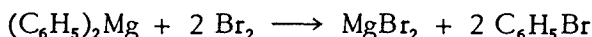


and that dimethylmagnesium reacts with acetyl chloride to form a product which, upon treatment with water, yields *t*-butyl alcohol. Strangely enough, he reported that treatment of diethylmagnesium with acetyl chloride leads, not to the formation of 2-ethyl-2-butanol, as might be expected, but of *t*-butyl alcohol.

Finding iodobenzene unreactive toward magnesium amalgam, Fleck prepared diphenylmagnesium by the interaction of magnesium and diphenylmercury. He characterized the reactions with water and oxygen, respectively, as follows:



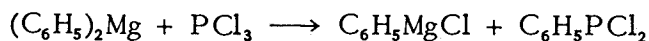
In the hope of obtaining phenylmagnesium bromide, analogous to the known phenylzinc bromide and phenylmercuric bromide, Fleck treated diphenylmagnesium with bromine, but because of the unfortunate use of an excess of bromine, was led to the conclusion that the reaction takes the course



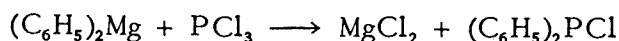
and that no stable compound of the formula $\text{C}_6\text{H}_5\text{MgBr}$ is thus formed.

It has since been demonstrated with a high degree of probability by Gilman and Brown⁶ that, sometime in the course of this experiment, Fleck must unwittingly have had phenylmagnesium bromide in hand.

Fleck's further attempt to prepare phenylmagnesium chloride by the reaction



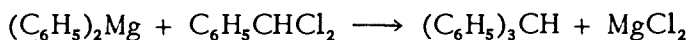
also came to naught. Apparently the reaction took the course



⁵ Fleck, *Ann.*, 276, 129-47 (1893).

⁶ Gilman and Brown, *J. Am. Chem. Soc.*, 52, 1181-5 (1930).

Fleck, however, effected one other reaction that was, in a sense prophetic of one of the now well-known Grignard reactions, namely:

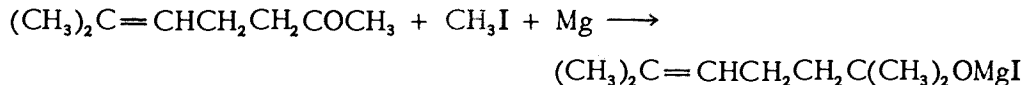


The immediate predecessor of the Grignard reactions was the Barbier synthesis, which, in turn, stemmed from the Wagner-Saytzeff synthesis.

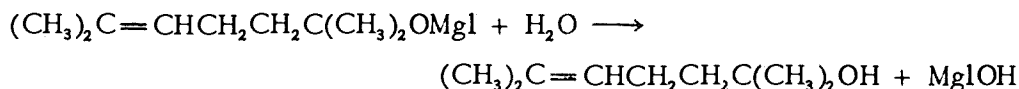
Rieth and Beilstein⁷ had shown that diethylzinc reacts with aldehydes and with acetone to give readily hydrolyzable compounds, although they did not correctly characterize their products.

Wagner and Saytzeff⁸ improved the technique by generating the zinc compound (from alkyl iodide and zinc) in the presence of a carbonyl compound and by subsequently hydrolyzing the resultant complexes to obtain alcohols of predetermined structure. The method was then applied by Saytzeff and many others, especially to the preparation of tertiary alcohols from ketones. The method, however, had decided disadvantages in that the yields in general were of the order of twenty to thirty percent and that the applicability was limited. (Methyl ketones, for example, were not amenable to such treatment.)

Barbier⁹ conceived the happy idea that an improvement might be effected by substituting the more reactive magnesium for zinc. Operating with natural dimethylheptenone, methyl iodide, and magnesium in ether, he brought about a vigorous reaction which he characterized as follows:



Subsequent hydrolysis yielded the desired carbinol:



The Barbier synthesis, although in some respects an improvement over the Wagner-Saytzeff synthesis, also had its defects, for in some cases, it gave negative results, and in many cases, results of very uneven quality.

When Victor Grignard (1871-1935) took up graduate work in chemistry at the University of Lyon under the direction of Barbier, the latter suggested that he continue the study of magnesium. Grignard soon reached what appeared to be an impasse in the further development of the Barbier synthesis. He reasoned that the effective intermediate in reactions of this kind must be a compound of the general formula RMgX , and believed that a new line of attack might be opened by generating this intermediate and then causing it to react with a carbonyl compound. Barbier, however, did not approve the idea, and it was abandoned temporarily.

⁷ Rieth and Beilstein, *Ann.*, 126, 241-7 (1863).

⁸ Wagner and Saytzeff, *Ann.*, 175, 351-74 (1875).

⁹ Barbier, *Compt. rend.*, 128, 110-1 (1898); *J. Chem. Soc.*, 76, I, 323 (1899).

When a change in his appointment afforded Grignard somewhat greater independence of action, he made some preliminary experiments along this line on his own initiative. He was soon able to demonstrate to Barbier by means of test-tube experiments that alkyl halides do react readily with magnesium in the presence of ethyl ether to produce ether-soluble reagents (presumably of the general formula RMgX) which will in turn react with carbonyl compounds with results superior in many cases to those obtained in the Barbier synthesis. Despite his earlier skepticism, Barbier broadmindedly commended Grignard upon the making of an important scientific discovery, and encouraged him to exploit it. Grignard's first description of the new reagents and of some of their properties and reactions appeared in 1900.¹⁰

A summary of Grignard's early papers and of his doctoral dissertation is to be found in the *Annales de chimie et de physique*.¹¹

General progress in the field was reviewed by Grignard in 1913,¹² and again in 1926.¹³

West and Gilman¹⁴ have prepared a bibliography of the literature relating to Grignard reagents and their reactions, covering the years 1900 through 1921.

A monograph covering the first quarter-century of the development of Grignard reagent chemistry has been prepared by Courtot,¹⁵ one of Grignard's early collaborators.

The preparative uses of Grignard reagents have been summarized by Runge¹⁶ in part I of volume XVI of Schmidt's "Chemie in Einzeldarstellung."

¹⁰ Grignard, *Compt. rend.*, 130, 1322 (1900); *Chem. Zentr.*, 1900, II, 33.

¹¹ Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).

¹² Grignard, *Bull. soc. chim.*, [4], 13, No. 11, Conference I-XXXVII (1913).

¹³ Grignard, *Bull. soc. chim.*, [4], 39, 1285-1321 (1926).

¹⁴ West and Gilman, "A Bibliography of the Grignard Reaction, 1900-1921," Reprint and Circular Series of the National Research Council, No. 24, 1922.

¹⁵ Courtot, "Le magnésium en chimie organique," Nancy, 1926, 351 pp.

¹⁶ Runge, "Organomagnesiumverbindungen," part I of "Organometallverbindungen," volume XVI of "Chemie in Einzeldarstellungen," edited by Julius Schmidt, Stuttgart, 1932 (photolithoprint reproduction, Edwards Brothers, Inc., Ann Arbor, 1943) 328 pp.

CHAPTER II

The Preparation of Grignard Reagents

Grignard's¹ method for the preparation of organomagnesium halides may be summarized as follows. One gram-atom of magnesium turnings (*ca.* 3.0×0.6 mm.) of 99.2-99.4 percent purity (the chief recognized impurity being iron) is placed in a well-dried, one-liter, two-necked, round-bottomed flask, fitted with a dropping funnel and a reflux condenser. One gram-molecular weight of the desired halide (say methyl iodide) is dissolved in an equal volume of anhydrous ethyl ether, and about 40-50 ml. of the solution is added to the magnesium. Almost immediately there appears at various points on the surface of the magnesium a brownish (in the case of iodides) or white (in the case of bromides) turbidity, accompanied by a very feeble effervescence. As the reaction accelerates, a white flocculation appears and the ether undergoes lively ebullition. A total of 250-300 g. of anhydrous ether is then added in two or three portions, with simultaneous cooling of the flask by means of a stream of cold air. The ebullition moderates, the flocculation (momentarily augmented) disappears almost immediately, the solution regains complete clarity, and the reaction is resumed with renewed vigor. The dropwise addition of the remainder of the ether-halide solution follows, and reaction is eventually completed by a half-hour reflux on the water-bath. There should then remain in the flask only a very fluid, nearly colorless liquid carrying a little iron in suspension.

This method Grignard found applicable to methyl, isopropyl, tertiary butyl, and secondary hexyl iodides, as well as to ethyl, propyl, isobutyl, isoamyl, and benzyl bromides.

In its principal essentials, this is substantially the method still employed in the production of the more readily available Grignard reagents for preparative purposes. Various modifications in apparatus and in details of operation have been suggested by observations and special studies on the effects of such factors as (1) the quality and quantity of metallic magnesium, (2) the presence of "activators" or "inhibitors," (3) the purity of halide, (4) the degree of ether dilution, (5) the rate of halide addition, and (6) the efficiency of stirring or other agitation on the ease of initiation of reaction, the rate of reaction, and the yield of Grignard reagent obtained.

¹ Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).

QUALITY AND QUANTITY OF MAGNESIUM

Although the presence of metallic impurities in the magnesium used may occasionally contribute to ease of initiation of reaction in cases of relatively unreactive halides, it is in general desirable to employ magnesium of the highest degree of purity attainable, in consideration both of the yield of Grignard reagent and the avoidance of "abnormal" side-reactions in subsequent utilization of the reagent.² Parenthetically, the specific nature of the impurities present is considerably more significant than the total quantity.

The yields of some Grignard reagents are not too greatly affected by the use of an inferior quality of magnesium. This is decidedly not true, however, in the cases of halides that have a pronounced tendency to undergo the Wurtz* or disproportionation reactions. Cusa and Kipping³ found, for example, that a European magnesium, supposedly containing less than 1 percent of impurities, consistently gave Grignard reagent yields of 35 percent with cyclohexyl bromide and 50 percent with cyclohexyl chloride. When an American magnesium (containing 0.50 percent aluminum, 0.10 percent silica, 0.05 percent iron, 0.05 percent manganese, and 0.05 percent copper) was substituted, the respective yields were 92 percent and 96 percent, confirming previous reports of American workers.⁴

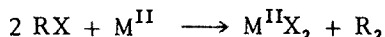
In view of the fact that reaction must necessarily take place at the metallic surface, the degree of division of the magnesium is obviously significant. In general, it may be expected that, *ceteris paribus*, the greater the surface present, the more readily a reaction may be initiated and the more rapidly it will proceed. However, other things seldom being equal, it is also true that extension of surface affords opportunity for undesirable surface contamination, and it has often been found in practice that very finely divided commercial magnesiums prove less reactive than magnesiums of ostensibly the same grade furnished in larger par-

²(a) Kharasch, Kleiger, Martin, and Mayo, *J. Am. Chem. Soc.*, 63, 2305-7 (1941); (b) Gilman, Zoellner, Selby, and Boatner, *Rec. trav. chim.*, 54, 584-94 (1935); (c) Reid and Ubbelohde, *J. Chem. Soc.*, 1948, 1597-601.

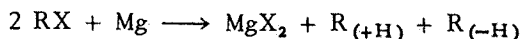
*As in common usage, the term "Wurtz reaction" is here loosely employed to signify a reaction of the general stoichiometric type



or



without implication as to mechanism. The corresponding "disproportionation reaction" involving magnesium may be indicated by the stoichiometric equation:

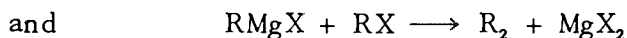
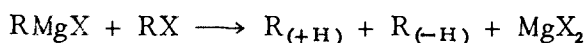
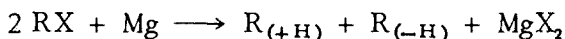
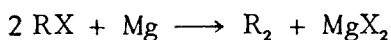


³Cusa and Kipping, *J. Soc. Chem. Ind.*, 53, 213-4T (1934).

⁴Gilman and McCracken, *J. Am. Chem. Soc.*, 45, 2462-6 (1923); Gray and Marvel, *ibid.*, 47, 2796-802 (1925); Gilman and Zoellner, *ibid.*, 53, 1945-8 (1931). See also: Gilman and Catlin, *Organic Syntheses*, Coll. Vol. I, 2nd ed., pp. 188-90, 1941.

tile sizes. Moreover, although a high rate of the desired reaction might be considered desirable on the ground that it discourages undesired side-reactions, it is not always an unmixed blessing.

Aside from the obvious practical necessity of avoiding too-violent ebullition of the ether medium, induced by over-rapid progress of an exothermal reaction, it is found in practice that too high a reaction rate materially reduces the yield of the Grignard reagent. This fact may probably be attributed to local concentration effects and local superheating. The principal competing reactions that operate (when high-grade magnesium is used) to reduce Grignard reagent yields are:



In general these reactions require (or at least are favored by) higher temperatures than the Grignard reagent formation reaction, and, in general, they are favored by relatively high halide (RX) concentrations.

It may be concluded, therefore, that in the preparation of Grignard reagents from the more reactive halides (see Relative Reactivities of Halides, p. 20) no advantage accrues to the use of the easily-contaminated finely divided magnesi-ums, and, further, that unless precautions are taken (by suitable dilution, adjustment of rate of addition of the halide, efficient agitation, and moderative cooling) to minimize local concentration and heat effects, actual disadvantage may be incurred. In an investigation of the optimum conditions for the preparation of ethylmagnesium iodide in which three size-grades of "a standard quality of American-made magnesium" turnings were used, Gilman and Meyers⁵ found no significant differences in yields (94-95 percent), provided sufficient time were allowed for complete reaction in each case.

When the less reactive halides are involved, the use of *thoroughly cleansed* finely divided magnesium is advantageous, if only from the standpoint of time economy.

A British patent⁶ describes a method and apparatus for continually cutting chips from a metal from which an organometallic halide is to be prepared, and supplying organic halide to the chip surfaces while they are being formed so that reaction occurs on the clean, nascent chip surfaces. A similar application of "mechanical activation" is discussed by Shaw.⁷

⁵ Gilman and Meyers, *J. Am. Chem. Soc.*, 45, 159-65 (1923).

⁶ Stevens, British Patent 571,539, Aug. 29, 1945; *Chem. Abstr.*, 41, P1696 (1947).

⁷ Shaw, *J. Applied Mechanics*, 15, No. 1, 37-44 (1948); *Chem. Abstr.*, 42, 2843 (1948).

The observation of Gaddum and French⁸ that electrolytically deposited * magnesium is extraordinarily reactive may or may not have a bearing on this point. They report that magnesium deposited by the electrolysis of an ethereal Grignard reagent solution reacts vigorously with cold water, violently with ethereal ethyl bromide, and readily with chlorobenzene. A freshly-deposited magnesium surface of this sort would be free of oxide and hydroxide contamination, and would, presumably, include many points of unsaturation. These qualities in themselves might well be sufficient to account for the degree of reactivity observed. However, it would be unwise to ignore the possibility that such deposits may include traces of halogen (*i.e.*, Mg_xMgX) which would certainly have an activating effect insofar as reactions with organic halides are concerned.

Although a small excess (5-10 percent) of magnesium is usually employed, there is, in general, no advantage to be gained by the use of a large excess of the metal. In the study just cited, for example, Gilman and Meyers⁵ found no appreciable change in yield when a 25 percent excess of magnesium was used. Even in the exceptional special cases in which the use of a large excess of magnesium has been recommended, as in the Gilman^{2b,9} preparations of allylmagnesium bromide (sixfold excess), and allylmagnesium chloride (threefold excess), it is doubtful that such an excess is at all necessary or advantageous when proper adjustment of other reaction factors is made.¹⁰

ACTIVATORS AND INHIBITORS

Grignard¹¹ found iodine a useful activator in initiating reaction between magnesium and aryl halides such as bromobenzene and the bromotoluenes.

Baeyer¹² pre-activated his magnesium with iodine, and found magnesium so activated effective in the preparation of Grignard reagents from iodoanilines and iododimethylanilines which had previously resisted reaction with magnesium, even in the presence of iodine.¹³ Baeyer's method consists in heating a 10-g. portion of magnesium filings in a long-necked 150-ml. flask over a free flame. Vigorous agitation is maintained during the portionwise addition of 5 g. of iodine, each small portion being permitted to disappear before the next is added. The temperature must be

⁸ Gaddum and French, *J. Am. Chem. Soc.*, 49, 1295-9 (1927).

*The study cited dealt with the electrolysis of ethereal solutions of phenylmagnesium bromide, benzylmagnesium bromide, and benzylmagnesium chloride; the specific source of the electrolytic magnesium tested is not stated.

⁹ Gilman and McGlumphey, *Bull. soc. chim.*, [4], 43, 1322-8 (1928).

¹⁰ *Cf.* the preparation of allylmagnesium chloride by Kharasch and Fuchs, *J. Org. Chem.*, 9, 359-72 (1944).

¹¹ Tissier and Grignard, *Compt. rend.*, 132, 1182-4 (1901).

¹² Baeyer, *Ber.*, 38, 2759-65 (1905).

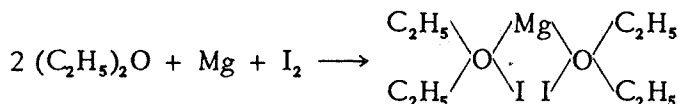
¹³ Baeyer and Villiger, *Ber.*, 36, 2774-96 (1903).

high, but not so high that the mass begins to fuse. For the quantities of materials designated, the time required is from one-quarter to one-half hour. The activated magnesium forms a matte-gray powder which turns brown on aging, and which must be carefully protected from moisture.

It is now generally recommended that Baeyer-activated magnesium be used only in relatively small quantities to initiate reaction, which then will usually proceed with ordinary magnesium.

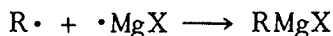
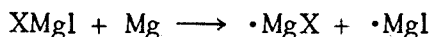
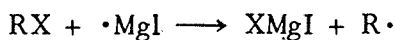
A simplified preparation of activated magnesium is described by Gilman and Kirby.¹⁴ Sodium-dried ether (5 ml.) is added dropwise to a well-stirred mixture of 5 g. of magnesium turnings or 30-80 mesh magnesium powder, 100 ml. of sodium-dried benzene and 2.5 g. of iodine. When the color of iodine has completely disappeared, the solvent is distilled with the aid of an oil-bath, the solid residue finally being maintained at 150-160° for about ten minutes. The activated magnesium may be transferred to a dry rubber-stoppered bottle. Reactivation before use is recommended, and may be effected by heating in a test-tube until gas evolution ceases and a color of iodine appears. Usually about 0.2 g. of activator is sufficient to initiate reaction.

Various explanations of the effectiveness of iodine as an activator have been offered. Zelinsky,¹⁵ who believed that iodine does not react with magnesium in benzene, attributed its activating properties to the local heat effects involved in formation of an ether complex.



Tingle and Gorsline¹⁶ offered the more plausible explanation that the activating agency is a "magnesium subiodide" (Mg_2I_2), though their formulation of the subsequent reaction mechanism would probably be received with general skepticism today.

Gomberg and Bachmann¹⁷ also attribute activation to magnesiumous iodide ($\cdot\text{MgI}$), and formulate the following free-radical mechanism:



They report, "We find that the addition of a small amount of magnesium iodide solution activates the metal just as well as does free iodine, so the doctrine of 'etching' is untenable. In this manner, we found it pos-

¹⁴ Gilman and Kirby, *Rec. trav. chim.*, 54, 577-83 (1935).

¹⁵ Zelinsky, *J. Russ. Phys.-Chem. Soc.*, 35, 399-404 (1903); *Chem. Zentr.*, 1903, II, 277.

¹⁶ Tingle and Gorsline, *Am. Chem. J.*, 37, 483-94 (1907).

¹⁷ Gomberg and Bachmann, *J. Am. Chem. Soc.*, 49, 236-57 (1927).

sible to bring about activation in some of the most resistant cases, such as *p*-bromobiphenyl, and apparently even with *p*-iododimethylaniline...."

Gilman and Vanderwal¹⁸ found that magnesium bromide etherate shortens the time necessary for initiation of reaction between *n*-butyl bromide and magnesium. (From a practical standpoint, of course, this reaction requires no activation.)

Gilman and Zoellner¹⁹ have investigated the effects on yields of various amounts of iodine used for activation purposes in the preparation of Grignard reagents from *n*-butyl bromide and *t*-butyl chloride. With no iodine at all and with 0.0125 atom equivalent of iodine per 0.05 mole equivalent of halide, the yields were about the same (*ca.* 96 percent for *n*-butylmagnesium bromide; *ca.* 83 percent for *t*-butylmagnesium chloride). With 1.0 atom equivalent of iodine per 0.05 mole equivalent of halide the corresponding yields were *ca.* 96 percent and *ca.* 80 percent, respectively. In general, intermediate quantities of iodine gave lower yields. They conclude that, except in very small or very large proportional quantities, iodine (*i.e.*, MgI_2) tends to reduce yields.

Among the numerous other activators that have been recommended are bromine, a readily reactive alkyl halide (such as ethyl bromide), a small amount of preformed Grignard reagent (such as ethylmagnesium bromide), hydrogen halides, various metallic halides, and various magnesium alloys. Probably the first four, at least, all owe their effectiveness in part at least to the introduction of small quantities of magnesium halide.

Taboury²⁰ recommended the use of bromine to facilitate the initiation of sluggish halide-magnesium reactions. His procedure is described as follows. Magnesium turnings (amount not specified) are placed in a suitably equipped flask. Then a small amount of ether-halide solution is introduced, followed by 1 ml. of bromine. Reaction begins within a few minutes. Ether-halide solution is added in small portions. Reaction is completed by thirty minutes reflux. This method brought α -naphthyl bromide, which required an hour and three-quarters reflux for initiation of reaction in the absence of bromine, into prompt reaction.

The efficacy of bromine as an activator has been confirmed by Gilman *et al.*,²¹ who found that the fumes from a glass stopper often constituted a sufficient quantity.

Activation by ethyl bromide or by ethylmagnesium bromide is exemplified in the method of Ehrlich and Sachs.²² They report: "When magnesium powder is covered with ether, and a little ethyl bromide is added, vigorous reaction soon sets in. The system is cooled, and most of the liquid

¹⁸ Gilman and Vanderwal, *Rec. trav. chim.*, 48, 160-2 (1929).

¹⁹ Gilman and Zoellner, *J. Am. Chem. Soc.*, 53, 1583-6 (1931).

²⁰ Taboury, *Ann. chim.*, [8], 15, 5-66 (1908).

²¹ Gilman, Peterson, and Schulze, *Rec. trav. chim.*, 47, 19-27 (1928).

²² Ehrlich and Sachs, *Ber.*, 36, 4296-9 (1903).

is decanted. An ether solution of bromodimethylaniline is then added with gentle warming, and reaction takes place readily, although not with quantitative yield." When magnesium powder or ribbon is added to bromodimethylaniline in ether solution, there is no appreciable reaction after a day's heating, even though iodine be added. The method of Ehrlich and Sachs probably has the double merit of supplying an activator and cleansing the metal surface.

Zelinsky (*loc. cit.*¹⁵) found methyl iodide an effective activator in the preparation of Grignard reagents from naphthenic chlorides. In a study of the effectiveness of various activators in initiating reaction between magnesium and β -bromostyrene, Gilman *et al.* (*loc. cit.*²¹) found methylene iodide, ethyl iodide, and β -bromoethyl ether effective in varying degrees. None of the organic halides they tested performed so satisfactorily as a small amount of previously prepared Grignard reagent (suitably, ethylmagnesium bromide).

Andrianov and Griбанова²³ recommend the use of a small amount of ethyl orthosilicate $[(C_2H_5O)_4Si]$ as an activator, and claim good results even in the absence of ethyl ether. In a sample procedure, a few drops of the silicate is added to 12 g. of metallic magnesium; about half the calculated quantity of organic halide is introduced dropwise. The remainder of the organic halide, dissolved in four or five parts [volumes?] of toluene or xylene is then added. The yields claimed for several organomagnesium halides prepared in this way are as follows: ethylmagnesium bromide (96 percent); isobutylmagnesium chloride (51 percent); isoamylmagnesium bromide (58 percent); *n*-hexylmagnesium bromide (60 percent); *n*-octylmagnesium bromide (35 percent); phenylmagnesium bromide (23–25 percent).

Hesse²⁴ mentions having attempted activation of reaction between magnesium and pinene hydrochloride with aluminum chloride with poor results. However, in this case, iodine and ethyl bromide also proved unsatisfactory, best results being obtained with a modification of the method of Ehrlich and Sachs (*loc. cit.*²²). Hufferd²⁵ reports that aluminum bromide, freshly prepared from aluminum and bromine, can often be used to initiate a Grignard preparation, but adds that the reagent has not been tried with any of the more difficult preparations. Gilman *et al.* (*loc. cit.*²¹) found zinc bromide, zinc iodide, mercuric iodide, cupric chloride, and gold chloride effective in varying degrees, but mercurous iodide, cupric bromide, ferrous and ferric chlorides, palladium chloride and potassium chloroplatinate ineffective.

²³ Andrianov and Griбанова, *J. Gen. Chem.* (U.S.S.R.), 8, 552–6 (1938); *Chem. Abstr.*, 32, 7892 (1938).

²⁴ Hesse, *Ber.*, 39, 1127–55 (1906).

²⁵ Hufferd, *J. Am. Chem. Soc.*, 49, 1845–6 (1927).

Hurd and Webb,²⁶ acting on privately communicated advice from Henry Gilman, tried a copper-magnesium alloy containing 12.75 percent copper in the preparation of Grignard reagents from α -bromo- β,β -diarylethylenes. They were thus able (with the aid of iodine and ethyl bromide activation) to reduce the time of preparation of the phenyl- α -naphthyl compound from a half-week with similarly activated magnesium turnings to a half-day with the alloy. They also state that the yield for the phenyl-*p*-tolyl compound was increased from 5 percent with magnesium to 51 percent with magnesium-copper alloy.

Gilman *et al.* (*loc. cit.*²¹) tried a number of magnesium alloys in the preparation of Grignard reagents from *n*-butyl chloride and styryl bromide. In each case, a small crystal of iodine was added at the beginning of the preparation. Among those tested, they list the following in the order of decreasing effectiveness: 12.75 percent copper, 2 percent copper, 50 percent copper, 50 percent tin, (ordinary magnesium turnings), 10 percent lead, 4.03 percent manganese, 1.83 percent manganese. They recommend an activator "conveniently and readily prepared, in less than ten minutes, by heating in an evacuated flask an alloy of magnesium containing 12.75 percent copper with about 20 percent by weight of iodine." The new "catalyst" is said to be "distinctly superior to Baeyer's activated magnesium."

Best results, in general, are claimed for the use of 0.25-0.50 g. of iodine-activated alloy with ordinary magnesium turnings and a 15-20 percent ether-halide solution.

When copper-magnesium alloy or the iodine-activated alloy is used as the sole source of magnesium in the preparation of Grignard reagents, the yield is usually materially lowered. In a study by Gilman and Zoellner,²⁷ "the powdered alloy, as such (2.0, 3.0, or 5.0 g.), or activated (1.5 or 2.0 g.), was covered with 5 ml. of ether; then twenty drops of the pure RX compound and a crystal of iodine... was added. The mixture was heated for ten minutes by means of a water-bath at 45°. Then the remainder of the halide (a total of 0.05 mole), mixed with 25 ml. of ether, was added over a period of thirty minutes with stirring. After all the halide had been added, the reaction mixture was stirred for an additional ten minutes." In Table II-I, representative yield values selected from those recorded by Gilman and Zoellner are set forth.*

In comparative studies by Johnson and Adkins²⁸ of the yields obtained from a 12 percent copper-88 percent magnesium alloy and from ordinary

²⁶ Hurd and Webb, *J. Am. Chem. Soc.*, 49, 546-59 (1927).

²⁷ Gilman and Zoellner, *J. Am. Chem. Soc.*, 53, 1581-3 (1931).

* It will be obvious to the experienced reader, without comment from the present authors, that the implied precision and reproducibility of the data in this and many of the succeeding tabulations of this chapter are spurious. In recording such data the authors endorse only the general qualitative trends indicated.

²⁸ Johnson and Adkins, *J. Am. Chem. Soc.*, 53, 1520-3 (1931); 54, 1943-7 (1932).

TABLE II-I

YIELDS (%) OF ORGANOMAGNESIUM HALIDES FROM MAGNESIUM,
MAGNESIUM-COPPER ALLOY, AND IODINE-ACTIVATED
MAGNESIUM-COPPER ALLOY

Halide	Cu-Mg	Cu-Mg-I ₂	Mg
<i>n</i> -C ₄ H ₉ Br	55.4-55.8	62.8	94.0
C ₆ H ₅ CH ₂ Cl	89.5	72.6	93.1
C ₆ H ₅ Br	82.3-83.9	79.0	94.7
4-CH ₃ C ₆ H ₄ Br	92.0	78.8	86.9

magnesium turnings, respectively, in reaction with sixteen different halides, the results were qualitatively confirmative of those of Gilman and Zoellner. The greatest difference in yields was obtained with allyl bromide: 72.3 ± 0.2 percent for magnesium and 5.7 ± 2.0 percent for the alloy.

In a heterogeneous reaction like that between an organic halide and metallic magnesium, it is, of course, difficult to distinguish between purely mechanical inhibition, which prevents effective contact between the ether-halide solution and the metal, and specific anticatalytic activity. The effect of a greasy film on the metal is certainly, and the effect of an oxide film is probably, of the purely mechanical type. Any contaminant which can react with the metallic magnesium, the organic halide, the solvent, or the Grignard reagent first produced to form or deposit an adherent, impervious coating on the metal will retard or prevent reaction. Some of the less ether-soluble Grignard reagents themselves tend to form such a coating. Many, though possibly not all, inhibiting effects can be accounted for in this way.

Bischoff²⁹ has reported that phenetole and various ketones and esters, and Ahrens and Stapler³⁰ that various aldehydes inhibit reaction between ethylene bromide and magnesium. Reychler³¹ found chloroform a marked inhibitor of reaction between magnesium and methyl iodide, ethyl iodide, ethyl bromide, or bromobenzene. He also reported that acetone, ethyl acetate, carbon tetrachloride and bromoform display inhibitory effects.

Freundler and Damond,³² experiencing the impossibility of preparing some Grignard reagents in ether contaminated with carbon disulfide, purposely used traces of that inhibitor to moderate the reaction of *n*-butyl bromide with magnesium (which they considered over-vigorous), and claimed to have obtained higher yields in that way. Most present-day workers would prefer other methods of controlling a vigorous reaction.

Gilman and Vanderwal (*loc. cit.*¹⁸) investigated the effects of various possible contaminants as inhibitors of reaction between *n*-butyl bromide and magnesium. The standard of comparison adopted was the time re-

²⁹ Bischoff, *Ber.*, 38, 2078-83 (1905).

³⁰ Ahrens and Stapler, *Ber.*, 38, 3260-7 (1905).

³¹ Reychler, *Bull. soc. chim.*, [3], 35, 803-11 (1906).

³² Freundler and Damond, *Bull. soc. chim.*, [3], 35, 106-11 (1906).

quired for 2 ml. of *n*-butyl bromide and 0.5 g. of magnesium turnings in 5 ml. of sodium-dried ether to yield a positive color test for Grignard reagent with Michler's ketone³³ (on the average, about seven and one-quarter minutes). Powdered glass and mercury (which might be introduced through the breakage of a mercury seal) were found to be without effect. Seasoned rubber (from an aged rubber stopper) or fresh rubber (cut from the inside of a new rubber stopper) were likewise without effect, but scrapings from the outside of a new rubber stopper were inhibitory. Gilman and Vanderwal attribute the inhibition to organic sulfur compounds, which are, they say, in general, inhibitors.³⁴ Dry air was without effect, but saturation of the ether with dry oxygen increased the induction period to eleven minutes. Carbon dioxide had a slight, and hydrogen chloride a more pronounced retarding effect.

Although nearly all experienced workers agree that operation in a thoroughly dried system is desirable, there appears to be some difference of opinion as to whether or not moisture actually inhibits Grignard reagent formation. On the basis of the test just described, Gilman and Vanderwal (*loc. cit.*¹⁸) conclude that it does. They found that the induction period of seven and one-quarter minutes for sodium-dried ether was increased to twenty minutes for commercial "anhydrous" ether. When 4.5 ml. of dried ether and 0.5 ml. of saturated ether was used, the period was thirty-three minutes, and with 2.5 ml. each of dried and saturated ether, about two hours.

It should be noted, however, that the times recorded are not the times necessary for the production of a small amount of Grignard reagent, but rather the times necessary for the production of a small excess of Grignard reagent over that sufficient to react with all the water present.*

From the results of a study of the influence of water in the synthesis of certain arylmagnesium bromides Jezierski³⁵ concluded that "water present in reagents checks the spontaneous course of the Grignard reaction; when the water is removed, the reaction starts instantly." He believed that the inhibitory influence of water is a "physical phenomenon."

Although they make no specific statement regarding induction times, Schmalfuss and Wetzels³⁶ maintain that moisture does not interfere with the preparation and subsequent reactions of Grignard reagents, provided due allowance is made for destruction of the Grignard reagent by water. They claim a 98 percent yield of methyldiphenylmethanol from benzo-

³³ Gilman and Schulze, *J. Am. Chem. Soc.*, 47, 2002-5 (1925).

³⁴ Cf. however, Hepworth, *J. Chem. Soc.*, 119, 1249-56 (1921).

*Concerning the limitations of this test, see Chapter III, Estimation and Detection of Grignard Reagents.

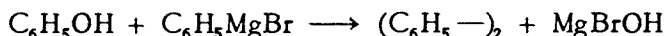
³⁵ Jezierski, *Roczniki Chem.*, 18, 567-73 (1938); *Chem. Abstr.*, 33, 4213 (1939).

³⁶ Schmalfuss and Wetzels, *J. prakt. Chem.*, [2], 109, 158-60 (1925); Schmalfuss, *ibid.*, [2], 113, 46-7 (1926).

phenone, operating in moist ether. They prepared phenyldimethylmethanol from methylmagnesium chloride and ethyl benzoate in 37 percent yield in dry ether and 38 percent yield in moist ether. The corresponding yields of phenyldiethylmethanol from ethylmagnesium bromide and benzoic acid reported were 53 percent and 64 percent.

In a relatively early study, Meyer and Tögel³⁷ investigated the effects of the addition of varying amounts of water to the reaction system in the course of the preparation of benzoic acid by Grignardization of bromobenzene and carbonation of the resultant phenylmagnesium bromide. In each of a series of ten experiments the Grignard reagent was prepared from 15.7 g. (0.1 mole) of bromobenzene and 2.4 g. (0.1 g.-atom) of magnesium in 50 ml. of ethyl ether. They report that when water was added to the various reaction systems in amounts varying from one to ten drops (1 drop = 0.0625 g.) the amounts of byproduct biphenyl formed increased from 1.95 to 63.5 percent, and the yields of benzoic acid obtained on subsequent carbonation decreased from 82.0 to 24.2 percent.

Attempts in the laboratories of the University of Chicago to verify the findings of Meyer and Tögel have failed.³⁸ With the reagent quantities specified the amount of biphenyl formed was substantially constant (8-13 percent), and was independent of the amount of water present. Among the various factors investigated the only one that materially affected the formation of biphenyl was variation of the quantity of ether present. (More concentrated halide solutions formed more biphenyl.) The source of the discrepancy is not apparent, but it is perhaps a relevant commentary on the work of Meyer and Tögel that they also claimed to have prepared biphenyl in 53-64 percent yields by means of the reaction:

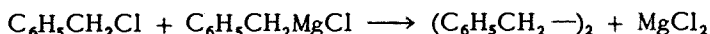


In a study of Wurtz product* formation and solvent coupling in the preparation of benzylmagnesium chloride and phenylmagnesium bromide in hydrocarbon solvents it was found that the yields of Wurtz and coupling products were independent of the (relatively small) amounts of water added during the reactions,³⁹ and it was at first supposed that the formation of these products was attributable to free-radical reactions induced by "catalytic" quantities of water in the presence of metallic magnesium. It was subsequently found, however, that substantially the same yields of these products are formed under rigorously anhydrous conditions.³⁸

³⁷ Meyer and Tögel, *Ann.*, 347, 55-92 (1906).

³⁸ Kane (with Kharasch), Dissertation, University of Chicago, 1941.

*The term "Wurtz product" is here loosely used to indicate a product of the type R_2 derived from an organic halide RX by the action of a metal. In the case of benzyl chloride such a product might arise in part from the Grignard reaction:



In the case of bromobenzene it must be otherwise formed.

³⁹ Kharasch, Goldberg, and Mayo, *J. Am. Chem. Soc.*, 60, 2004 (1938).

PURITY OF HALIDE

A good grade of commercial halide is often found satisfactory for the preparation of the corresponding Grignard reagent, especially in the cases of readily prepared reagents such as *n*-butylmagnesium bromide and phenylmagnesium bromide. However, in general, the desirability of a high degree of purity in the halide is emphasized. It is recommended, for example, that benzyl chloride be freshly distilled.⁴⁰

Several investigators have reported difficulty in preparing α -naphthylmethylmagnesium halides in good yields.⁴¹ Gilman and Kirby⁴² emphasize the necessity for the use of halide of high purity. They found α -naphthylmethyl chloride prepared by direct chlorination of the corresponding hydrocarbon unsatisfactory, but obtained estimated yields of about 80 percent with chloride prepared by treatment of the carbinol with thionyl chloride.

Miller and Bachman⁴³ reported that 9-bromoanthracene did not react appreciably with magnesium and ether even in a sealed tube at 200°. Bachmann and Kloetzel,⁴⁴ however, report yields as high as 86 percent. They specify the use of a good grade (99.7 percent) of finely divided, thoroughly cleansed magnesium with a bromide melting at 100° or higher. Bromide melting below 100° is said to be unsuitable, and ordinary magnesium turnings reacted to the extent of only 55 percent in twenty-four hours.

RELATIVE QUANTITY OF ETHER

No thorough investigation of the optimum proportions of ether to be used in the preparation of Grignard reagents has been made. Doubtless these depend in varying degrees upon a number of interrelated experimental conditions, such as: the reactivity of the halide, the tendency of the halide to undergo the Wurtz or disproportionation reactions, the tendency of the halide to react with its own Grignard reagent, the solubility of the Grignard reagent, the rate of addition of the halide, the efficiency of stirring, etc. In view of the fact that high concentrations and higher temperatures tend to favor side-reactions, there is probably for each group of more or less closely related halides a range of ether dilutions below which yields tend to drop off rapidly, and above which any gain in yield is offset by the additional cost and labor involved in handling larger quantities of ether.

⁴⁰ Gilman and Catlin, *Organic Syntheses*, Coll. Vol. I, 2nd ed., pp. 471-3, 1941; Adkins and Zartman, *ibid.*, Coll. Vol. II, pp. 606-7, 1943.

⁴¹ Weitzenbock and Lieb, *Monatsh.*, 33, 549-65 (1912); Mayer and Sieglitz, *Ber.*, 55B, 1835-59 (1922); Conant, Small, and Sloan, *J. Am. Chem. Soc.*, 48, 1743-57 (1926).

⁴² Gilman and Kirby, *J. Am. Chem. Soc.*, 51, 3475-8 (1929).

⁴³ Miller and Bachman, *J. Am. Chem. Soc.*, 57, 766-71 (1935).

⁴⁴ Bachmann and Kloetzel, *J. Org. Chem.*, 3, 55-61 (1938).

In a study in which ether-halide solutions were added slowly, with efficient stirring, to ether-covered magnesium, activated by a small crystal of iodine, Gilman and McCracken⁴⁵ noted some rather striking variations in yield with variations in degree of dilution in the cases of *n*-butyl bromide, bromobenzene and benzyl chloride. Data, selected from their tabulation, are presented in Table II-II.*

TABLE II-II
EFFECTS OF ETHER DILUTION OF HALIDE ON
GRIGNARD REAGENT YIELDS

Halide	Et ₂ O/RX (moles)	Yield RMgX (%)
<i>n</i> -C ₄ H ₉ Br	0.4	52.1
	0.5	71.2
	1.0	92.0
	1.0	52.6
C ₆ H ₅ Br	2.0	68.1
	3.0	72.6
	4.0	91.8
	5.0	94.5
	6.0	94.3
	1.0	38.6
C ₆ H ₅ CH ₂ Cl	2.0	80.6
	3.0	86.7
	4.0	88.7
	10.0	93.3

The molar ratios of ether to halide recommended by Gilman and McCracken are: *n*-butyl bromide, 1.3 : 1.5; bromobenzene, 4 : 5; benzyl chloride, 6 : 7.

In their study of the optimum conditions for the preparation of ethylmagnesium iodide, Gilman and Meyers (*loc. cit.*⁵) apparently did not investigate in detail the effect of ether dilution upon yields, but found an ether-halide molar ratio of approximately 8 : 1 satisfactory (94-95 per cent yield). Incidentally, they found that use of half the ether to cover the magnesium and the other half to dilute the halide gave results superior to those obtained by the method originally employed by Grignard (*loc. cit.*¹).

In a report on a similar study of the preparation of *t*-butylmagnesium chloride, Gilman and Zoellner⁴⁶ recommend an ether-halide molar ratio of seven or eight to one.

Gilman and McGlumphey (*loc. cit.*⁹) report that, in the preparation of allylmagnesium bromide, a 7.5 : 1 ether-halide molar ratio gives yields superior to those obtained with 6 : 1 or 5 : 1 ratios.

⁴⁵Gilman and McCracken, *Rec. trav. chim.*, 46, 463-72 (1927).

*In recording these data the present authors do not endorse their implied precision and reproducibility; the general qualitative trend indicated is accepted as significant.

⁴⁶Gilman and Zoellner, *J. Am. Chem. Soc.*, 50, 425-8 (1928).

For the corresponding chloride, Kharasch and Fuchs (*loc. cit.*¹⁰) found an ether-halide ratio of approximately 3 : 1 quite satisfactory, although the Grignard reagent is relatively insoluble and is thus prepared in suspension. The two preparations, of course, are not strictly comparable, for, aside from the different characteristics of the two halides and their respective Grignard reagents, Kharasch and Fuchs operated at ice-bath temperatures, whereas Gilman and McGlumphey did not resort to cooling.

In general, when no previous data are available, and when there is no reason to suspect the halide employed of markedly abnormal behavior, it may be regarded as a safe rule to allow sufficient ether to cover the metallic magnesium plus sufficient to dilute the halide to give a solution containing 25-30 percent of halide by volume.

Gilman and Vanderwal⁴⁷ have investigated the effect of relative ether-halide concentrations on time of reaction initiation for four halides: *n*-butyl bromide, *n*-butyl chloride, bromobenzene, and benzyl chloride. One-half gram of magnesium turnings was activated with 5 drops of 25 percent ether-iodine solution (except in the case of *n*-butyl bromide, which required no activation). Seven milliliters of an ether-halide solution was then added. The time necessary for appearance of a Grignard reagent color test (Gilman and Schulze, *loc. cit.*³³) was noted. In each case, the time-concentration curve passed through a minimum. The "optimal" halide concentrations by volume were: *n*-butyl bromide, *ca.* 55 percent; *n*-butyl chloride, *ca.* 70 percent; bromobenzene 25-30 percent; benzyl chloride 25-30 percent.

RATE OF ADDITION OF HALIDE

Like the degree of dilution of the halide, the rate of addition of the halide solution must be regarded as one of several interdependent factors. In general, however, relatively slow addition is to be recommended for iodides, most bromides, and a few of the more reactive chlorides.

Efficient agitation, high dilution, and, in some cases, cooling of the reaction mixture may be employed to minimize the time required for a comparatively large-scale preparation, but there is usually a limit below which unprofitable sacrifices in yield are made.

A rough indication of the effect of rate of halide addition on Grignard reagent yields in small-scale runs is afforded by data taken from two studies by Gilman *et al.*⁴⁸ and presented in Table II-III.* In the orthodox preparations (*Slow Add'n*) 0.054 gram-atom of magnesium was placed in

⁴⁷ Gilman and Vanderwal, *Bull. soc. chim.*, [4], 45, 641-4 (1929).

⁴⁸ Gilman, Zoellner, and Dickey, *J. Am. Chem. Soc.*, 51, 1576-83, 1583-7 (1929).

* In recording these data the present authors do not endorse their implied precision and reproducibility; the general qualitative trend indicated is accepted as significant.

TABLE II-III

EFFECT OF RATE OF HALIDE ADDITION ON GRIGNARD REAGENT YIELDS

Halide	Average yield (%)		Halide	Average yield (%)	
	Slow Add'n	Rapid Add'n		Slow Add'n	Rapid Add'n
C ₂ H ₅ Br	93.1	86.6	n-C ₇ H ₁₅ Br	88.8	72.9
n-C ₃ H ₇ Br	91.7	82.5	n-C ₈ H ₁₇ Br	88.4	73.3
i-C ₃ H ₇ Br	84.0	70.5	n-C ₄ H ₉ Cl	91.2	90.6
n-C ₄ H ₉ Br	94.0	79.2	n-C ₄ H ₉ I	85.6	67.8
i-C ₄ H ₉ Br	87.2	76.7	C ₆ H ₅ CH ₂ Cl	93.1	92.9
s-C ₄ H ₉ Br	77.7	61.6	C ₆ H ₅ Br	94.7	89.8
t-C ₄ H ₉ Br	25.1	17.8	2-CH ₃ C ₆ H ₄ Br	92.7	88.3
n-C ₅ H ₁₁ Br	88.6	73.2	3-CH ₃ C ₆ H ₄ Br	88.0	81.3
i-C ₅ H ₁₁ Br	88.0	70.2	4-CH ₃ C ₆ H ₄ Br	86.9	83.3
s-C ₅ H ₁₁ Br	66.8	49.2	1-C ₁₀ H ₇ Br	94.8	91.7
t-C ₅ H ₁₁ Br	23.7	19.1	2-C ₁₀ H ₇ Br	83.8	81.3
n-C ₆ H ₁₃ Br	92.0	77.2			

an oven-dried flask, together with 6.5 ml. of dried ether, 0.04 g. of iodine and 0.2 ml. of halide. Reaction was initiated by reflux at 45°. The remainder of a total of 0.05 mole of halide, dissolved in the remainder of a total of 30 ml. of ether, was then added gradually, with stirring, over a period of thirty to thirty-five minutes. Completion of reaction was effected by five to ten minutes reflux, in the cases of the alkyl halides, or fifteen to thirty minutes reflux, in the cases of the aryl halides. In the other study (*Rapid Add'n*) the conditions were the same except that after initiation of reaction the remainder of the ether-halide solution was added all at once.

In an extension of the studies just summarized, Gilman *et al.* (*loc. cit.*⁴⁸) investigated the behavior of a considerable number of alkyl and aralkyl chlorides. In general, there was little or no significant difference in yields of organomagnesium chlorides between the slow-addition and rapid-addition experiments.

In the preparation of ethylmagnesium iodide, Gilman and Meyers (*loc. cit.*⁵) found that, up to forty-five minutes, the yield increased with increase in time of addition of the halide solution (9.5 g. of ethyl iodide in 25 ml. of ether).

For the preparation of *t*-butylmagnesium chloride, a rate of addition of the halide-ether solution of about 90 drops or 1.4 ml. per minute is recommended,⁴⁶ and it is stated that the slower the addition the higher the yield.⁴⁹

AGITATION OF THE REACTION MIXTURE

In view of the probable inducement of undesirable side reactions by local superheating or local concentration effects, efficient stirring should

⁴⁸ Puntambeker and Zoellner, *Organic Syntheses*, Coll. Vol. I, 2nd ed., pp. 524-6, 1941.

be regarded as a routine requirement in all Grignard reagent preparations. In the preparation of ethylmagnesium iodide, Gilman and Meyers (*loc. cit.*³³) found that efficient stirring materially enhanced the yield. In preparations of suspensions of relatively insoluble Grignard reagents such as, for example allylmagnesium chloride (Kharasch and Fuchs, *loc. cit.*¹⁰) or 9-anthrylmagnesium bromide (Bachmann and Kloetzel, *loc. cit.*⁴⁴), vigorous stirring is not only desirable, but imperative.

RELATIVE REACTIVITIES OF HALIDES

It is generally known that, on the basis of (1) ease of initiation of reaction with magnesium (as judged by the necessity for the use of activators), (2) length of time necessary for reaction with magnesium to become detectable, and (3) rate of disappearance of magnesium after reaction begins, the organic halides stand in the order of decreasing reactivity: $RI > RBr > RCl$, when the organic radical R remains the same throughout. This, of course, implies nothing about relative yields of the respective Grignard reagents or of the yields of products that may be obtained in subsequent reactions of the Grignard reagents. On the whole, however, it is evident that relatively high reactivity with respect to the criteria mentioned is usually accompanied by relatively high reactivity in side-reactions. Therefore, it is true in general that, of the Grignard reagents, $RMgX$, conveniently preparable, the one prepared from the least reactive halide is likely to be obtained in highest yield and to perform most satisfactorily in subsequent reactions.

As regards variations in halide activity when the halogen X remains the same, but the radical R is varied, it may be said that, despite a few apparent exceptions (scarcely surprising in the case of a heterogeneous reaction), the general rule is that halides (RX) in which the radical R is weakly electronegative, are more reactive toward magnesium in the presence of ethyl ether than halides in which the radical R is moderately or strongly electronegative.*

However, it cannot be too strongly emphasized that steric effects, relative product solubilities, relative diffusibilities, and even more obscure factors may lead to individual exceptions to the general tendencies described in the foregoing generalizations.

Rudd and Turner⁵⁰ have studied the relative reactivities of several pairs of halides toward magnesium by means of competitive reactions. Magnesium (0.025 gram atom), activated with 1.5 mg. of iodine, was allowed to react completely with a mixture of 0.025 mole each of halides I and II in 50 ml. of ether. The solution was then analyzed for halide ions.

* Concerning relative electronegativities of organic radicals, see: Kharasch and Reinmuth, *J. Chem. Education*, 5, 404-18 (1928); 8, 1703-48 (1931); Kharasch, Reinmuth, and Mayo, *ibid.*, 11, 82-96 (1934); 13, 7-19 (1936).

⁵⁰ Rudd and Turner, *J. Chem. Soc.*, 1928, 686-91.

TABLE II-IV
RELATIVE REACTIVITIES OF HALIDE PAIRS TOWARD MAGNESIUM

Halide Pair	Halide Ions in Sol'n (% Total)		
	Cl ⁻	Br ⁻	I ⁻
C ₂ H ₅ Cl-C ₂ H ₅ Br	24	76	—
<i>n</i> -C ₃ H ₇ Cl- <i>n</i> -C ₃ H ₇ Br	19	81	—
<i>n</i> -C ₄ H ₉ Cl- <i>n</i> -C ₄ H ₉ Br	9	91	—
C ₆ H ₅ CH ₂ Cl- <i>n</i> -C ₄ H ₉ Br	27	73	—
CH ₃ Cl-CH ₃ I	27	—	73
C ₂ H ₅ Cl-C ₂ H ₅ I	29	—	71
<i>n</i> -C ₃ H ₇ Cl- <i>n</i> -C ₃ H ₇ I	44	—	56
<i>n</i> -C ₄ H ₉ Cl- <i>n</i> -C ₄ H ₉ I	46	—	54
CH ₃ Br-CH ₃ I	—	71	29
C ₂ H ₅ Br-C ₂ H ₅ I	—	46	54
<i>n</i> -C ₃ H ₇ Br- <i>n</i> -C ₃ H ₇ I	—	57	43
<i>n</i> -C ₄ H ₉ Br- <i>n</i> -C ₄ H ₉ I	—	27	73
C ₆ H ₅ Br-C ₆ H ₅ I	—	52	48
2-CH ₃ C ₆ H ₄ Br-2-CH ₃ C ₆ H ₄ I	—	94	6
3-CH ₃ C ₆ H ₄ Br-3-CH ₃ C ₆ H ₄ I	—	88	12
4-CH ₃ C ₆ H ₄ Br-4-CH ₃ C ₆ H ₄ I	—	84	16

No account was taken of possible side-reactions. The data are recorded in Table II-IV.*

Strangely enough, Rudd and Turner report that a mixture of methyl chloride and methyl bromide did not react. Gilman and Vanderwal⁵¹ investigated this halide pair under slightly different conditions. Five grams of magnesium, activated with a trace of iodine was covered with 75 g. of ether. A mixture of the gaseous halides, with the chloride in excess, was led into the ether until the magnesium had completely disappeared. Subsequent analysis revealed a bromide-chloride ratio of approximately 5:1.

In a study somewhat similar to that of Rudd and Turner, St. John and St. John⁵² allowed 0.5 mole each of two halides to compete in reaction with 0.5 mole of magnesium. The halide pairs were so chosen that the Grignard reagent formed from one member of each pair could be determined by gas analysis. Total Grignard reagent formation was determined by acid titration. The percentage yields of Grignard reagents from the respective halide pairs were as follows: *n*-butyl bromide 33, bromobenzene

* In view of the demonstrated effect of the presence of a relatively reactive halide upon the apparent reactivity toward magnesium of a relatively unreactive halide (see Grignard Reagent Preparation by "Entrainment" p. 38), the quantitative significance of data obtained from such competitive reactions is highly questionable. In the opinion of the present authors, however, the qualitative differences indicated are real and significant.

⁵¹ Gilman and Vanderwal, *Bull. soc. chim.*, [4], 45, 135-7 (1929).

⁵² St. John and St. John, *Rec. trav. chim.*, 55, 585-8 (1936).

67; ethyl bromide 47, 1-naphthyl bromide 53; *n*-butyl bromide 46, benzyl chloride 54.

The comparative yields from the first two pairs of halides are rather striking in view of the results of other methods of comparing relative halide reactivities. St. John and St. John conclude that the presence of one halide affects the reactivity of the other (a possibility also suggested by Rudd and Turner). However, here again, there was no attempt to evaluate the products of side-reactions, which might throw a different light on the results.

In a further study of the relative reactivities of halides toward magnesium, Gilman and Vanderwal⁵³ treated 0.5 g. of magnesium turnings with 0.0187 mole of halide in 5 ml. of dry ether. Aliquot samples were withdrawn at definite intervals and submitted to a color test for a Grignard reagent (Gilman and Schulze, *loc. cit.*³³). The times observed are recorded in Table II-V.

TABLE II-V

RELATIVE REACTIVITIES OF HALIDES TOWARD MAGNESIUM

Halide	Time for G.R. Test	Halide	Time for G.R. Test
CH ₃ I	3.5 min.	<i>n</i> -C ₆ H ₁₃ I	27.5 min.
C ₂ H ₅ I	4.5 min.	<i>n</i> -C ₇ H ₁₅ Br	12.5 min.
<i>n</i> -C ₃ H ₇ Br	7.5 min.	<i>n</i> -C ₈ H ₁₇ Br	16.3 min.
<i>n</i> -C ₃ H ₇ I	6.4 min.	(CH ₂) ₅ CHBr	25.0 min.
<i>n</i> -C ₄ H ₉ Br	7.5 min.	C ₆ H ₅ CH ₂ Cl	25.0 min.
<i>n</i> -C ₄ H ₉ I	7.6 min.	C ₆ H ₅ Br	32.0 min.
<i>i</i> -C ₄ H ₉ Br	5.4 min.	2-C ₁₀ H ₇ Br	Several hours
<i>s</i> -C ₄ H ₉ Br	3.5 min.		

Under these conditions *n*-butyl chloride and 1-naphthyl bromide give no test in several years; cyclohexyl chloride, no test in two years; *p*-dibromobenzene, no test in one year. The *t*-butyl bromide could not be compared with the other butyl bromides, for, under these conditions, although it reacts with magnesium, it does not form a Grignard reagent.

Several of the aromatic halides were tested under similar conditions, but with the addition of ten drops of 5 percent ether-iodine solution as activator. The times observed were: *p*-dibromobenzene, 15.0 min.; *p*-bromotoluene, 16.5 min.; *m*-bromotoluene, 20.5 min.; *o*-bromotoluene, 23.0 min.; 2-naphthyl bromide, 21.2 min.; 1-bromonaphthalene, 25.8 min.

SOME ILLUSTRATIVE PREPARATIONS IN THE CLASSICAL MANNER

Apparatus. The container of choice for Grignard reagent preparations is a round-bottomed, three-necked flask of the standard-taper ground-glass-joint type. It should be fitted with an efficient mechanical stirrer, a condenser, and a dropping funnel. The dropping funnel may be replaced by various other attachments or by a ground-glass plug as occasion demands.

⁵³ Gilman and Vanderwal, *Bull. soc. chim.*, [4], 45, 344-9 (1929).

The stirrer shaft may be provided with a mercury seal as a guard against atmospheric contamination. The authors prefer a seal of the Trubore type. Stirrers of this type are available in all-glass construction. Equally satisfactory models have been machined from brass in the University of Chicago shops. The authors have found a stirrer blade of the plate-glass crescent type the most satisfactory for general purposes.

Generally speaking, any fairly efficient reflux condenser will give adequate service. In warm, humid weather, however, a condenser of the interior-coolant type which is not subject to external sweating has obvious advantages. The open end of the condenser should be protected with calcium chloride and soda-lime tubes in series, or with a trap.

For the average occasional preparation no further protection against atmospheric contamination is necessary. In all quantitative studies, however, and when large numbers of preparations are being made, particularly in humid weather, it is advantageous to operate in an inert atmosphere, preferably nitrogen. Tank nitrogen may be used with no treatment other than a passage through a drying (calcium chloride) tower. The authors prefer to remove traces of oxygen by passage over heated copper granules. A Pyrex tube, packed with copper granules and externally heated with a Nichrome coil controlled by a variable transformer, has proved satisfactory. Satisfactory nitrogen-purification trains are also described by Fieser⁵⁴ and by Kohler *et al.*⁵⁵

To insure complete dryness the authors place in the flask the magnesium to be used, and admit deoxygenated, dried nitrogen to the apparatus through a special plug which replaces the dropping funnel. When most of the air has been swept from the apparatus the flask is thoroughly flamed with a cool Bunsen flame to drive off adsorbed moisture, passage of nitrogen being continued throughout.

For all quantitative studies and for preparations in which the presence of residual metallic magnesium is objectionable, filtration of the Grignard solution through a sintered-glass disc or a glass-wool plug is effected with the aid of nitrogen pressure. When filtration is unnecessary and when the normal order of addition is used, subsequent reactions are carried out in the original flask.

The "cyclic reactor." A "cyclic reactor," especially useful for the preparation in good yields of Grignard reagents that react readily with the halides from which they are prepared is described by Rowlands *et al.*^{55,1} as follows.

"We have obtained gratifying results by a system which attains high dilution by continuously recycling a moderate initial amount of solvent

⁵⁴Fieser, *J. Am. Chem. Soc.*, 46, 2639-47 (1924).

⁵⁵Kohler, Stone, and Fuson, *J. Am. Chem. Soc.*, 49, 3181-8 (1927).

^{55,1}Rowlands, Greenlee, and Boord, *Abstracts of Papers*, 117th Meeting, A.C.S., Philadelphia, Pa., April 9-13, 1950, p. 8-L.

(usually ether). The halide is slowly added to the solvent stream as it enters the top of a vertical tube packed with amalgamated magnesium turnings. The Grignard reagent formed is swept into and accumulated in a heated flask while the solvent is refluxed back into the reaction tube. A 'hump' in the return line to the flask insures that the magnesium is covered with solvent at all times; the amalgamation is essential.

"Using this device we have consistently obtained yields of 85-95 percent from allyl bromide and 80-87 percent from crotyl bromide. Benzyl bromide gave a 96 percent yield and benzhydryl bromide 25 percent. With our apparatus Newman and Wotiz^{55,2} got 98 percent yield from *n*-butyl-propargyl bromide."

Gaertner^{55,3} has also made use of this device for the preparation of various thenylmagnesium chlorides. The best percentage yields obtained by Gaertner in the "cyclic reactor" and the percentage yields obtained by conventional methods (in parentheses) were: 2-thenylmagnesium chloride, 98.0 (7.3); 2-thianaphthenylmethylmagnesium chloride, 93.0 (61.0); 3-thianaphthenylmethylmagnesium chloride, 99.0 (36.0).

Reagents. For general purposes magnesium turnings of the highest grade of purity obtainable (sublimed metal) are recommended. When it appears advisable to use more finely divided magnesium the turnings may be reduced to the desired size in a mill or even in a hand mortar.

For many routine preparations ordinary commercial anhydrous ether is entirely satisfactory. For quantitative studies, and for some special preparations, sodium-dried ether is indicated. It is claimed⁵⁶ that commercial ethers may be dried sufficiently for use as Grignard reaction solvents by adding an amount of silicon tetrachloride equivalent to the amount of water present and separating by filtration the precipitated silicic acid. Dehydration and general purification of ether by distillation from methylmagnesium iodide (any readily available Grignard reagent should serve as well) has also been recommended.⁵⁷

By personal communication from Mr. George V. D. Tiers of the University of Chicago the authors are apprised of a method of solvent purification (particularly dehydration and deoxygenation) which they have not seen described elsewhere. The method appears to be rather generally applicable to ethers (*e.g.*, ethyl ether, tetrahydrofuran, glycol and polyglycol diethers), tertiary amines (*e.g.*, triethylamine, *N*-methylmorpholine), and aromatic hydrocarbons (*e.g.*, benzene, toluene).

^{55,2} Newman and Wotiz, *J. Am. Chem. Soc.*, 71, 1292-7 (1949). See also: Wotiz, *ibid.*, 72, 1639-42 (1950); Wotiz and Palchak, *ibid.*, 73, 1971-2 (1951); Wotiz, Matthews, and Lieb, *ibid.*, 73, 5503-4 (1951).

^{55,3} Gaertner, (a) *J. Am. Chem. Soc.*, 73, 3934-7 (1951); (b) *ibid.*, 74, 766-7 (1952); (c) *ibid.*, 74, 2185-8 (1952).

⁵⁶ Buchanan and Simpson, U. S. Patent 2,446,408, Aug. 3, 1948; *Chem. Abstr.*, 42, P8208 (1948).

⁵⁷ Mackle, *Proc. Roy. Irish Acad.*, 52B, 49-56 (1948); *Chem. Abstr.*, 43, 3780 (1949).

Solvent batches of any convenient size may be processed; for illustrative purposes the procedure is outlined as follows. To one litre of good-quality commercial ethyl ether, dried over anhydrous potassium hydroxide, in a reflux apparatus protected against access of moisture, is added 3-5 g. of benzophenone. The resultant solution is brought to reflux, and small particles of freshly-cut metallic sodium are added at intervals.

For obvious reasons the purification process is of indefinite length, and may require as much as two days. A solution of desirable purity is characterized by a persistent intense deep-blue coloration. A yellowish or greenish coloration indicates the necessity for the addition of more benzophenone (followed by further sodium addition). The purified solvent may be distilled, if desired, in a stream of dried nitrogen, but this precaution is unnecessary except for extremely oxygen-sensitive solvents (*e.g.*, isopropyl ether).

Although many commercial halides are of excellent purity and may be used without preliminary treatment in routine preparations, it is, in general, desirable that the halide be at least redistilled. Benzyl chloride, for example, should always be freshly distilled. A few halides give satisfactory results only when special standards of purity are met.

General method for preparation of organomagnesium halides. The method of Gilman *et al.* (*loc. cit.*⁴⁸), outlined in connection with the discussion of the effect of rate of halide addition upon yields of Grignard reagents, may be regarded as a general, though probably not an optimal, method for the preparation of organomagnesium halides. It is applicable to *n*-alkyl bromides, many secondary alkyl bromides and the more reactive aryl bromides. Some indication of the yields to be expected is to be derived from the "slow addition" column of Table II-III.

Using this method with *n*-alkyl bromides, and treating the resultant Grignard reagents with allyl bromide, Wilkinson⁵⁸ obtained the indicated overall percentage yields of the following 1-alkenes: pentene, 94; hexene, 77; heptene, 90; octene, 89; nonene, 85.

Yields of twenty-one Grignard reagents prepared by a similar general method are reported by Gilman and McCracken.⁵⁹

Methylmagnesium chloride.⁶⁰ One hundred grams of magnesium turnings in a suitably equipped flask surrounded by an ice-salt bath are covered with anhydrous ether. The chilled ether is saturated with commercial methyl chloride which has been passed through a calcium chloride tower. The cooling bath is then removed, and the mixture is allowed to come to

⁵⁸ Wilkinson, *J. Chem. Soc.*, 1931, 3057-62.

⁵⁹ Gilman and McCracken, *J. Am. Chem. Soc.*, 45, 2462-6 (1923).

⁶⁰ (a) Marvel and Moon, *J. Am. Chem. Soc.*, 62, 45-9 (1940). See also: (b) Houben, *Ber.*, 39, 1736-53 (1906); (c) Houben, Boedler, and Fischer, *Ber.*, 69B, 1766-88 (1936); (d) Schmalzfuss, *J. prakt. Chem.*, 108, 88-90 (1924); (e) Gilman, Zoellner, Selby, and Boatner, *Rec. trav. chim.*, 54, 584-94 (1935); (f) Coburn, *Organic Syntheses*, 27, 65-7 (1947).

room temperature. If reaction does not begin, the cooling and saturation are repeated. Once reaction has been initiated 500 ml. of anhydrous ether is added, and methyl chloride is slowly passed into the mixture until all the magnesium has disappeared. A grayish precipitate of methylmagnesium chloride separates during the reaction. If ether loss becomes excessive more ether is added during the course of the reaction.

By treatment of a methylmagnesium chloride suspension, prepared as described, with *o*-bromobenzaldehyde, Marvel and Moon obtained an 87 percent yield of the expected secondary alcohol. By treatment of a suspension prepared in a similar manner with benzophenone, Schmalfuss obtained a 98 percent yield of the expected tertiary alcohol. In a preparation by Houben *et al.*,^{60c} a variation of this method showed a 99.7 percent yield of Grignard reagent (on the basis of the magnesium consumed) by acid titration.

Ethylmagnesium chloride⁶¹ may be prepared in essentially the same manner as methylmagnesium chloride. Houben *et al.*,^{60c} report a 98.6 percent yield by acid titration.

General method for the preparation of alkylmagnesium chlorides.⁶² A general method, applied to the preparation of ethyl-, *n*-propyl-, isopropyl-, *n*-butyl-, isobutyl-, *s*-butyl-, and *t*-butylmagnesium chlorides, is described by Huston and Langham essentially as follows. Magnesium turnings (54.7 g., 2.25 moles) are placed in a two-liter flask equipped with a mercury-sealed stirrer, an inlet tube for nitrogen, a reflux condenser, and a dropping funnel. After the system has been swept with dry nitrogen, 4–5 g. of alkyl chloride, dissolved in 100 ml. of anhydrous ethyl ether, is added. Initiation of reaction is facilitated by the addition of a small amount of ethyl bromide dissolved in 100 ml. of ethyl ether. The remainder of 2 moles of alkyl chloride, dissolved in 800 ml. of ethyl ether, is added from the dropping funnel at a rate to maintain moderate refluxing. (In the case of *t*-butyl chloride the rate of addition is exceptionally slow.) After completion of the chloride addition, a slow stream of nitrogen is introduced, and stirring is continued for two hours. Reaction is completed by overnight standing.

Although it is stated that Grignard reagent samples were evaluated by acid titration of aliquot portions, no values are reported.

Tertiary alkylmagnesium chlorides.⁶³ In a suitably equipped flask are placed a few small crystals of iodine and 98 g. of freshly turned mag-

⁶¹ Kyriakides, *J. Am. Chem. Soc.*, 36, 657–63 (1914).

⁶² Huston and Langham, *J. Org. Chem.*, 12, 90–5 (1947).

⁶³ (a) Whitmore and Badertscher, *J. Am. Chem. Soc.*, 55, 1559–67 (1933). See also: (b) Whitmore and Houk, *ibid.*, 54, 3714–8 (1932); (c) Greenwood, Whitmore, and Crooks, *ibid.*, 60, 2028–30 (1938); (d) Gilman and Zoellner, *ibid.*, 50, 425–8 (1928); *Rec. trav. chim.*, 47, 1058–63 (1928); (e) Puntambeker and Zoellner, *Organic Syntheses*, Coll. Vol. I, 2nd ed., pp. 524–6, 1941; (f) Rheinboldt, Mott, and Motzkus, *J. prakt. Chem.*, 134, 257–81 (1933).

nesium. The bottom of the flask is heated with a small flame until the iodine begins to vaporize, and is then allowed to cool. Thirty milliliters of a solution of four moles of the tertiary halide in 500 ml. of dry ether is added. If reaction does not begin under these conditions a few drops of ethyl bromide or *n*-butyl bromide is added. After reaction has started and progressed for a few minutes, 200 ml. of dry ether is added to the reaction mixture. Four hundred seventy-five milliliters of ether-chloride solution is then added, with efficient stirring, at a rate not faster than one drop per second. Even slower addition is advisable in the case of the higher tertiary chlorides. After the first portion of the chloride has been added the remainder of the solution is diluted with an additional 300 ml. of dry ether and is added at the same rate with continued stirring. The mixture is permitted to reflux during the ether-chloride addition, no external cooling being applied. Heating after completion of the chloride addition is unnecessary; stirring, however, is continued for one hour.

Whitmore and Badertscher claim the indicated percentage yields (as determined by acid titration) of the following *t*-alkylmagnesium chlorides: *t*-C₄H₉MgCl, 80.0; *t*-C₅H₁₁MgCl, 73.6; *n*-C₄H₉(CH₃)₂CMgCl, 79.0; *n*-C₅H₁₁(CH₃)₂CMgCl, 59.9; CH₃(C₂H₅)₂CMgCl, 70.4; CH₃(C₂H₅)(*n*-C₃H₇)CMgCl, 77.7; CH₃(C₂H₅)(*n*-C₄H₉)CMgCl, 70.0; (C₂H₅)₃CMgCl, 58.3. Substantially the same method was used for *t*-C₄H₉MgCl by Whitmore and Houk, who claim an 85 percent yield (by titration), and by Greenwood *et al.*, who claim yields of 75-85 percent (by titration). Rheinboldt *et al.* used a method differing only in detail for 1-2 mole lots of *t*-C₄H₉MgCl, and claim yields of Grignard reagent as high as 90 percent. According to Gilman and Zoellner, who used a similar method for *t*-C₄H₉MgCl, large runs give better yields than small ones, and 200-mesh magnesium powder gives better yields than fine magnesium turnings. Upon carbonation of a solution of *t*-C₄H₉MgCl prepared by a similar method, Puntambeker and Zoellner obtained trimethylacetic acid in 61-63 percent yields from magnesium turnings, and in 69-70 percent yields from magnesium powder.

Allylmagnesium chloride.⁶⁴ Magnesium turnings (80 g.) and dry ether (400 ml.) are placed in a suitably equipped flask, which is cooled in an ice-bath. The mixture is vigorously stirred, and allyl chloride (230 g.) in dry ether (400 ml.) solution is added from a dropping funnel at such a rate that little or no gas evolution takes place. Formation of the Grignard reagent begins almost immediately, and is usually complete within ten hours. The allyl Grignard reagent so prepared is a white crystalline solid which forms a smooth suspension in ether.

The chloride reacts in suspension to give better yields of products than can be obtained by the use of clear solutions of the corresponding bromide. Treatment of α -chloro- β -diethylaminoethane with an excess of

⁶⁴Kharasch and Fuchs, *J. Org. Chem.*, 9, 359-72 (1944).

allylmagnesium chloride suspension gave an 85 percent yield of the expected unsaturated amine (on the basis of the chloroalkylamine expended).

β -Methallylmagnesium chloride.⁶⁴ This compound may be prepared in the same manner as allylmagnesium chloride.

Cyclohexylmagnesium chloride.⁶⁵ In a suitably equipped 1-liter flask 26.7 g. (1.1 g.-atom) of magnesium is covered with about 100 ml. of anhydrous ether, and 15 ml. of pure cyclohexyl chloride and a crystal of iodine are added. Heat is then applied until five to ten minutes after the iodine color has disappeared. An additional 125 ml. of ether is added, stirring is begun, and the remainder of a total of 118.5 g. (121 ml., 1.0 mole) of cyclohexyl chloride, dissolved in 225 ml. of ether, is added with moderate rapidity (0.5–0.75 hr.), with cooling if necessary. (In the preparation of cyclohexylmagnesium bromide the addition of the ether-halide solution must be much slower.) Stirring and refluxing are continued for fifteen to twenty minutes after completion of the addition.

Grignard reagent yields of about 92 percent (by titration) are claimed. Carbonation leads to the expected carboxylic acid in about 93 percent yield (on the basis of Grignard reagent present) or 85 percent overall. (Cyclohexylmagnesium bromide is obtained in about 80 percent yield, with subsequent carbonation leading to a 66 percent overall yield of the carboxylic acid.)

Cinnamylmagnesium chloride.⁶⁶ Cinnamyl chloride (m. 7–8°) prepared from cinnamyl alcohol (m. 32–33°) by the action of thionyl chloride in chloroform-pyridine solution was used. Reaction is initiated by the addition of 20 drops of pure, freshly distilled chloride to 15 g. of 30–60 mesh magnesium covered with 25 ml. of dry ether. A solution of 30.5 g. of chloride in 275 ml. of ether is then added very slowly (2.25 hrs.) with vigorous stirring.

Titration yields of 83–87 percent are reported. Carbonation leads to α -phenyl- α -vinylacetic acid in 62–66 percent yields.

Phenylmagnesium bromide.⁶⁷ Magnesium turnings (20 g.), bromobenzene (3–5 g.) and dry ether (150 ml.) are combined. One gram of iodine-activated magnesium is added, and the mixture is stirred until reaction begins. The remainder of a total of 78.5 g. of bromobenzene, dissolved in 200 ml. of ether, is then added in the course of a half-hour.

⁶⁵(a) Gilman and Zoellner, *J. Am. Chem. Soc.*, 53, 1945–8 (1931). See also: (b) Gilman and Catlan, *Organic Syntheses*, Coll. Vol. I, 2nd ed., pp. 188–90, 1941.

⁶⁶Gilman and Harris, (a) *Rec. trav. chim.*, 50, 1052–5 (1931); (b) *J. Am. Chem. Soc.*, 53, 3541–6 (1931); (c) Young, Ballou, and Nozaki, *J. Am. Chem. Soc.*, 61, 12–15 (1939); (d) Campbell and Young, *J. Am. Chem. Soc.*, 69, 688–90 (1947).

⁶⁷(a) Hershberg, *Helv. Chim. Acta*, 17, 351–8 (1934). See also: (b) Allen and Converse, *Organic Syntheses*, Coll. Vol. I, 2nd ed., pp. 226–7, 1941; (c) Gilman, St. John, and St. John, *Rec. trav. chim.*, 48, 593–6 (1929).

By treatment of a Grignard solution so prepared with allyl bromide, Hersberg obtained an 82 percent overall yield of allylbenzene. Allen and Converse report an overall yield of about 75 percent of the expected carbinol upon treatment of a Grignard solution prepared by a similar method with ethyl acetate. Using a similar method, Gilman *et al.* claim Grignard reagent yields of 96-98 percent (by acid titration).

Mesitylmagnesium bromide.⁶⁸ In a suitably equipped 3-liter flask is placed 48 g. of fine magnesium turnings, 100 g. of bromomesitylene and 150 g. of ether. Reaction is initiated by the addition of a little iodine or Gilman's iodine-activated copper-magnesium alloy. Stirring is begun, and a solution of 298 g. of bromide in 600 g. of ether is added at a rate to maintain brisk refluxing. After the addition is completed refluxing is continued until nearly all the magnesium has disappeared.

Isodurene is obtained in 52-60 percent yields by treatment of a Grignard solution so prepared with dimethyl sulfate.

9-Phenanthrylmagnesium bromide.⁶⁹ A mixture of 6.45 g. of 9-bromophenanthrene, 0.65 g. of magnesium, 0.05 g. of iodine, 15 ml. of ether and 15 ml. of benzene is refluxed under nitrogen for four to five hours, at the end of which time 95-98 percent of the theoretical amount of magnesium should have reacted.

Bachmann describes the treatment of Grignard solutions so prepared with some fifteen co-reactants. Among the percentage yields of "normal" products reported are: CO_2 , 70; $\text{C}_6\text{H}_5\text{CHO}$, 72; $(\text{C}_6\text{H}_5)_2\text{CO}$, 76.

9-Anthrylmagnesium bromide.⁷⁰ For use in the preparation of this Grignard reagent pure (99.7 percent), cleaned magnesium ribbon was pulverized in a Wiley mill, washed twice with acetone, and dried. (Ordinary magnesium turnings reacted to the extent of only 55 percent in twenty-four hours.) The purity of the halide is also important; 9-bromoanthracene melting below 100° is not suitable. Of the several methods tried by Bachmann and Kloetzel the following gave the best yield of Grignard reagent (86 percent by acid titration).

A mixture of 2.57 g. of 9-bromoanthracene, 0.50 g. of magnesium powder, 5 drops of ethyl bromide and 20 ml. of ether is refluxed for twenty-four hours, with frequent agitation during the first few hours.

Styrylmagnesium bromide.⁷¹ A mixture of 7.32 g. of 30-80 mesh magnesium, 30 drops of styryl bromide, 0.08 g. of iodine and 20 ml. of ether is refluxed for about fifteen minutes to initiate reaction. When reaction

⁶⁸(a) Smith and MacDougall, *J. Am. Chem. Soc.*, 51, 3001-8 (1929); (b) Smith, *Organic Syntheses*, Coll. Vol. II, pp. 360-2, 1943.

⁶⁹(a) Bachmann, *J. Am. Chem. Soc.*, 56, 1363-7 (1934). See also: (b) Pschorr, *Ber.*, 30, 3128-9 (1906).

⁷⁰Bachmann and Kloetzel, *J. Org. Chem.*, 3, 55-61 (1938).

⁷¹Gilman, Zoellner, Selby, and Boatner, *Rec. trav. chim.*, 54, 584-94 (1935).

TABLE II-VI

SOME GRIGNARD REAGENT PREPARATIONS IN THE CLASSICAL MANNER

Halide, RX	Yield G.R., RMgX (%)	Co-reactant	Yield, "Normal" Product (%)	Ref.
C ₂ H ₅ Br	...	(C ₂ H ₅ O) ₂ CO	82-88	15
<i>i</i> -C ₃ H ₇ Br	...	CH ₃ CHO	53-54	4
<i>n</i> -C ₄ H ₉ Br	...	O=(CH ₂) ₂	60-62	5
<i>n</i> -C ₄ H ₉ Br	...	HCO ₂ C ₂ H ₅	83-85	3
<i>n</i> -C ₄ H ₉ Br	87-91	...	...	10
<i>i</i> -C ₄ H ₉ Br	74	...	...	21
<i>s</i> -C ₄ H ₉ Cl	...	CO ₂	76-86	7
<i>n</i> -C ₅ H ₁₁ Br	...	(C ₂ H ₅ O) ₃ CH	45-50	2
<i>i</i> -C ₄ H ₉ CH ₂ Cl	89	(<i>i</i> -C ₃ H ₇) ₂ CO	4*	19
(CH ₂) ₅ CHBr	ca. 80	H ₂ C=CHCH ₂ Br	60-64	14
CH ₃ (<i>n</i> -C ₄ H ₉)CHBr	...	H ₂ O	50-53	16
4-BrC ₆ H ₄ Br	...	H ₂ O	70 [†]	17
(CH ₃) ₃ SiOSi(CH ₃) ₂ CH ₂ Cl	80	...	...	22
2-F ₃ CC ₆ H ₄ Br	98	CO ₂	86	12
4-F ₃ CC ₆ H ₄ Br	...	CO ₂	90	12
C ₆ H ₅ CH ₂ Cl	91	...	...	10
C ₆ H ₅ CH ₂ Cl	...	(C ₂ H ₅) ₂ SO	70-75	6
C ₆ H ₅ CH ₂ Cl	...	(C ₆ H ₅) ₂ CO	54-59 [‡]	1
C ₆ H ₅ CH ₂ Cl	93	...	...	11
4-CH ₃ C ₆ H ₄ Br	...	CH ₃ COC ₂ H ₅	71	18
4-CH ₃ OC ₆ H ₄ CH ₂ Cl	90	...	...	23
1-C ₁₀ H ₇ Br	96	...	...	10
1-C ₁₀ H ₇ Br	...	CO ₂	68-70	9
1-C ₁₀ H ₇ Br	...	(C ₂ H ₅ O) ₂ CO	68-73	20
1-C ₁₀ H ₇ CH ₂ Cl	ca. 80	CO ₂	59	7
1-C ₁₀ H ₇ CH ₂ Cl	88-92	H ₂ O	80	24
4-(C ₂ H ₅) ₃ SiC ₆ H ₄ Br	...	H ₂ O	83	25
4-C ₆ H ₅ CH ₂ OC ₆ H ₄ CH ₂ Cl	90	...	...	23
<i>n</i> -C ₁₈ H ₃₇ MgBr	85	...	...	26
(C ₆ H ₅) ₂ C=C(C ₆ H ₅)Br	...	CO ₂	89	13

* The ketone undergoes enolization to the extent of 90 percent.

[†]The Wurtz product, (4-BrC₆H₄—)₂, was formed to the extent of 10.0 percent; benzene, from 4-BrMgC₆H₄MgBr, to the extent of 12.8 percent, was also recovered.[‡]The product isolated in this case is the olefin (*i.e.*, the dehydrate of the "normal" addition product).

REFERENCES FOR TABLE II-VI

- (1) Adkins and Zartman, *Organic Syntheses*, Col. Vol. II, pp. 606-7, 1943.
- (2) Bachmann, *Organic Syntheses*, Coll. Vol. II, pp. 323-5, 1943.
- (3) Coleman and Craig, *Organic Syntheses*, Coll. Vol. II, pp. 179-81, 1943.
- (4) Drake and Cook, *Organic Syntheses*, Coll. Vol. II, pp. 406-7, 1943.
- (5) Dreger, *Organic Syntheses*, Coll. Vol. I, 2nd ed., pp. 306-8, 1941.
- (6) Gilman and Catlin, *Organic Syntheses*, Coll. Vol. I, 2nd ed., pp. 471-3, 1941.
- (7) Gilman and Kirby, *J. Am. Chem. Soc.*, 57, 3475-8 (1929).
- (8) Gilman and Kirby, *Organic Syntheses*, Coll. Vol. I, 2nd ed., pp. 361-4, 1941.

- (9) Gilman, St. John, and Schulze, *Organic Syntheses*, Coll. Vol. II, pp. 425-7, 1941.
- (10) Gilman, St. John, and St. John, *Rec. trav. chim.*, 48, 593-6 (1929).
- (11) Gilman, Zoellner, and Dickey, *J. Am. Chem. Soc.*, 51, 1576-83, 1583-7 (1929).
- (12) Jones, *J. Am. Chem. Soc.*, 69, 2346-50 (1947).
- (13) Koelsch, *J. Am. Chem. Soc.*, 54, 2045-8 (1932).
- (14) Lespieau and Bourguel, *Organic Syntheses*, Coll. Vol. I, 2nd ed., pp. 186-7, 1941.
- (15) Moyer and Marvel, *Organic Syntheses*, Coll. Vol. II, pp. 602-4, 1943.
- (16) Noller, *Organic Syntheses*, Coll. Vol. II, pp. 478-80, 1943.
- (17) Quelet, *Bull. soc. chim.*, [4], 41, 933-6 (1927).
- (18) Rupe and Burgin, *Ber.*, 44, 1218-25 (1911).
- (19) Whitmore and George, *J. Am. Chem. Soc.*, 64, 1239-42 (1942).
- (20) Whitmore and Loder, *Organic Syntheses*, Coll. Vol. II, pp. 282-3, 1943.
- (21) Whitmore and Lux, *J. Am. Chem. Soc.*, 54, 3448-54 (1932).
- (22) Roedel, *J. Am. Chem. Soc.*, 71, 269-72 (1949).
- (23) Van Campen, Meisner, and Parmerter, *J. Am. Chem. Soc.*, 70, 2296-7 (1948).
- (24) Grummitt and Buck, *J. Am. Chem. Soc.*, 65, 295-6 (1943).
- (25) Grüttner and Krause, *Ber.*, 50, 1559-68 (1917).
- (26) Jones, *J. Am. Chem. Soc.*, 69, 2350-4 (1947).

begins 40 ml. of ether is added. Then a solution of 18.3 g. of bromide in 47 ml. of ether is added over the course of an hour, with refluxing and stirring. Refluxing and stirring are continued for fifteen minutes after completion of the addition.

A 90 percent yield of Grignard reagent (by acid titration) is reported. The magnesium used in this study was of 99.8 percent purity, containing 0.15 percent copper, 0.06 percent iron, and 0.02 percent silica. Various other samples of magnesium turnings gave yields of 68-78 percent, depending upon the source.

Triphenylmethylmagnesium bromide.⁷² The bromide is preferred for preparation of the Grignard reagent because, unlike the chloride,⁷³ it does not require iodine activation. A mixture of 16.2 g. of triphenylmethyl bromide, 1.34 g. (0.12 g. excess) of magnesium ribbon, 25 ml. of ether and 50 ml. of benzene is heated on a steam bath. The solution is protected against oxygen and against light. The reaction is apparently completed in less than an hour. The solution is filtered through sintered glass.

Acid titration and hydrocarbon isolated upon hydrolysis indicate a Grignard reagent yield of 95-97 percent. Carbonation leads to nearly quantitative yields of triphenylacetic acid.

Other Grignard reagent preparations. Some references to other Grignard reagent preparations described in more or less detail in the literature are assembled in Table II-VI.

⁷² Gomberg and Bachmann, *J. Am. Chem. Soc.*, 52, 2455-61 (1930).

⁷³ Schmidlin, *Ber.*, 39, 628-36 (1906).

Because of the relatively lower yields of Grignard reagents attainable and the susceptibility of the Grignard reagents to side-reactions, iodides are not recommended for preparative purposes, and no examples are included in the foregoing illustrative preparations. In a study by Houben *et al.* (*loc. cit.*^{60c}), in which methods of preparation were varied somewhat according to the halide concerned, relative yields of several normal and iso alkylmagnesium chlorides, bromides, and iodides, were determined by titration on the basis of the magnesium (99.8 percent) consumed, (Table II-VII).*

TABLE II-VII
RELATIVE YIELDS OF SOME NORMAL AND ISO
ALKYLMAGNESIUM HALIDES

R (in RX)	Yields (%) of RMgX		
	Chlorides	Bromides	Iodides
CH ₃	99.7	98.9	100.0
C ₂ H ₅	98.6	97.0	96.4
<i>n</i> -C ₃ H ₇	98.2	92.5	91.8
<i>i</i> -C ₃ H ₇	93.9	83.5	57.5
<i>n</i> -C ₄ H ₉	98.5	88.5	85.0
<i>i</i> -C ₄ H ₉	98.9	82.3	79.6
<i>i</i> -C ₅ H ₁₁	96.3	79.1	75.1
<i>n</i> -C ₆ H ₁₃	97.2	86.8	79.9
<i>n</i> -C ₇ H ₁₅	97.5	88.1	79.0
<i>n</i> -C ₈ H ₁₇	96.2	86.8	81.7
<i>n</i> -C ₁₀ H ₂₁	96.0	86.8	78.0
<i>i</i> -C ₁₁ H ₂₃	89.7	62.1	42.9
<i>n</i> -C ₁₆ H ₃₃	96.0	81.4	79.7

SOME LIMITATIONS OF THE CLASSICAL METHOD

From the rather meagre experimental evidence available it would appear that, in general, the *gem*-dihalides are poor prospects for Grignard reagent preparation. Emschwiller⁷⁴ claims to have prepared methylene-magnesium bromide [H₂C(MgBr)₂] and iodide [H₂C(Mgl)₂] from methylene bromide and iodide, respectively, asserting that methane is liberated upon hydrolysis of the reaction mixture. Chang and Chao-Lun Tseng⁷⁵ report confirmation of Emschwiller's results in so far as methylene iodide is concerned, but add that the maximum yield is 10 percent, and that the supposed Grignard reagent does not react with acetone, benzophenone, Michler's ketone, or carbon dioxide.

*In recording these data the present authors do not endorse their implied precision and reproducibility; the general qualitative trend indicated is accepted as significant.

⁷⁴Emschwiller, *Compt. rend.*, 183, 665-7 (1926); *Chem. Abstr.*, 21, 563 (1927).

⁷⁵Chang and Chao-Lun Tseng, *Trans. Sci. Soc. China*, 7, 243-51 (1932), *Chem. Abstr.*, 26, 5544 (1932).

According to Chao-Lun Tseng,⁷⁶ pure anhydrous chloroform, bromoform, or carbon tetrachloride do not react with magnesium in ethyl ether. Addition of iodine, methyl iodide, or ethyl iodide had no "catalytic" effect. Preliminary experiments showed that carbon tetrabromide reacts vigorously with magnesium.

According to Henne,⁷⁷ neither dichlorodifluoromethane, chlorodifluoromethane, nor bromodifluoromethane react with molten sodium, the implication being that they are similarly inert toward magnesium.

Chang and Chao-Lun Tseng⁷⁸ report that neither benzylidene chloride ($C_6H_5CHCl_2$) nor benzylidyne chloride ($C_6H_5CCl_3$) react with magnesium in the absence of a "catalyst." Addition of ethylmagnesium iodide initiates reaction which leads to the formation of a yellow amorphous product (apparently a mixture of hydrocarbons of high molecular weight).

In general the *vic*-dihalides are also poor risks in Grignard reagent preparation. Tissier and Grignard⁷⁹ found that, with magnesium, ethylene bromide undergoes an internal Wurtz reaction to yield ethylene and magnesium bromide.* The "crystalline products" obtained by Ahrens and Stapler⁸⁰ from magnesium, ethylene bromide, and aromatic aldehydes were doubtless Werner complexes of the approximate average composition $RCHO \cdot MgBr_2 \cdot O(C_2H_5)_2$. On distillation they yielded the respective aldehydes and ethyl ether. Bischoff⁸¹ was similarly unsuccessful in attempts to prepare ethylenemagnesium bromide ($BrMgCH_2CH_2MgBr$) from ethyl bromide. Courtot⁸² treated 2,3-dimethyl-3,4-dibromobutene with magnesium and obtained 2,3-dimethylbutadiene (biisoprenyl).

By a combination of the internal Wurtz and the Grignardization reactions, von Braun *et al.*⁸³ have prepared several unsaturated Grignard reagents from tribromides, *e.g.*,

⁷⁶Chao-Lun Tseng, *Natl. Central. Univ. Sci. Repts.*, Ser. A, 1, No. 2, 1-4 (1931); *Chem. Abstr.*, 26, 2166 (1932); *Trans. Sci. Soc. China*, 7, 233-7 (1932); *Chem. Abstr.*, 26, 5544 (1932).

⁷⁷Henne, *J. Am. Chem. Soc.*, 60, 2275-6 (1938).

⁷⁸Chang and Chao-Lun Tseng, *Trans. Sci. Soc. China*, 7, 239-42 (1932); *Chem. Abstr.*, 26, 5544 (1932).

⁷⁹Tissier and Grignard, *Compt. rend.*, 132, 835 (1901); *Chem. Zentr.*, 1901, I, 999.

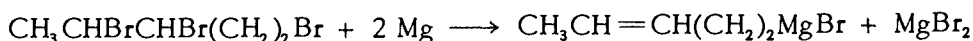
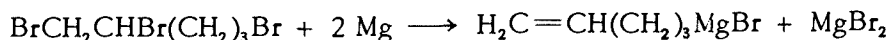
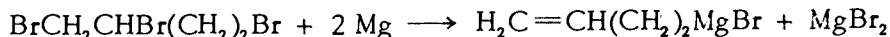
*Incidentally this reaction constitutes the basis of a method for the preparation of small quantities of anhydrous ethereal magnesium bromide more convenient in some respects than the classical method of Zelinsky, *J. Russ. Phys.-Chem. Soc.*, 35, 399-404 (1903); *J. Chem. Soc.*, 84, I, 802 (1903), and Menshutkin, *Z. anorg. chem.*, 49, 34-45 (1906).

⁸⁰Ahrens and Stapler, *Ber.*, 38, 1296-8, 3259-67 (1905).

⁸¹Bischoff, *Ber.*, 38, 2078-83 (1905).

⁸²Courtot, *Bull. soc. chim.*, [3], 35, 969-88 (1906).

⁸³(a) von Braun and Sobecki, *Ber.*, 44, 1039-48 (1911); (b) von Braun and Deutsch, *Ber.*, 44, 3699-706 (1911); (c) von Braun and Kohler, *Ber.*, 51, 79-96 (1918); (d) von Braun and Kirschbaum, *Ber.*, 52B, 1713-6 (1919).



Somewhat more surprising is the report by Henne (*loc. cit.*⁷⁷) that 1,1-difluoro-2-iodoethane reacts with magnesium to yield fluoroethylene together with a mixture of magnesium fluoride and iodide, and that 1,1-difluoro-2-bromoethane does not react with magnesium at all. Brice *et al.*⁸⁴ have found that heptafluorobromopropane reacts with magnesium to form a Grignard reagent which liberates heptafluoropropane upon hydrolysis, but emphasize the necessity of maintaining rigorously anhydrous conditions during the Grignardization.

More recently Haszeldine^{84,1} reports that both the purity of the magnesium used and the nature of the reaction solvent employed exert a profound influence on success in the preparation of a Grignard reagent from heptafluoroiodopropane.

Adjacency less than vicinal of the halogen atoms in a dihalide may also interfere with Grignardization. Bischoff (*loc. cit.*⁸¹) was unsuccessful in the attempt to prepare trimethylenemagnesium bromide [$\text{BrMg}(\text{CH}_2)_3\text{MgBr}$] from trimethylene bromide. Zelinsky and Gutt,⁸⁵ who treated trimethylene bromide with magnesium in ether, and then carbonated the resultant reaction mixture, isolated cyclopropane and propene, together with a 20 percent yield of suberic acid [$\text{HO}_2\text{C}(\text{CH}_2)_6\text{CO}_2\text{H}$].

Exceptions might be expected, however, as in cases in which the 3-halogen atom of a 1,3-dihalide is relatively unreactive. Lespieau and Deluchat⁸⁶ found that, although, under the conditions employed by them, treatment of 2,4-dibromo-1-butene with magnesium yielded chiefly the Wurtz product (2,7-dibromo-1,7-octadiene), some Grignard reagent [$\text{H}_2\text{C}=\text{CBr}(\text{CH}_2)_2\text{MgBr}$] was formed, for treatment of the reaction mixture with methyl chloromethyl ether produced a small amount of 2-bromo-5-methoxy-1-butene. Similarly, although Henne and Whaley⁸⁷ had reported that 1,1,1-trifluoro-3-chloropropane reacts neither with ethylmagnesium bromide nor magnesium, McBee and Truchan,⁸⁸ by maintaining rigorously anhydrous conditions, were able to prepare a Grignard reagent which, upon oxidation, yielded 39.5 percent of the expected alcohol, and, upon carbonation, yielded 42.5 percent of the expected acid.

⁸⁴ Brice, Pearlson, and Simons, *J. Am. Chem. Soc.*, 68, 968-9 (1946).

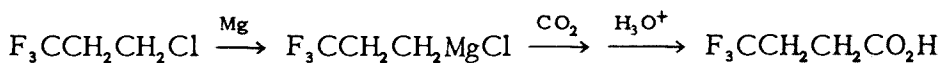
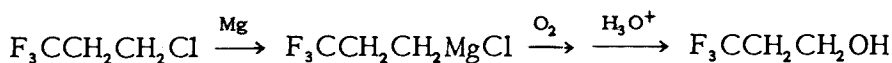
^{84,1} Haszeldine, *J. Chem. Soc.*, 1952, 3423-8.

⁸⁵ Zelinsky and Gutt, *Ber.*, 40, 3049-50 (1907).

⁸⁶ Lespieau and Deluchat, *Compt. rend.*, 183, 889-91 (1926); *Chem. Zentr.*, 1927, I, 260.

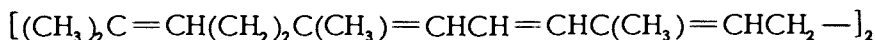
⁸⁷ Henne and Whaley, *J. Am. Chem. Soc.*, 64, 1157-9 (1942).

⁸⁸ McBee and Truchan, *J. Am. Chem. Soc.*, 70, 2910-1 (1948).

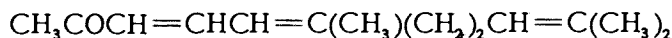


According to von Braun and Sobecki,⁸⁹ treatment of ethereal tetramethylene bromide with magnesium and subsequent carbonation of the reaction mixture yields cyclobutane, a very small amount of cyclopentanone, and sebacic [$\text{HO}_2\text{C}(\text{CH}_2)_8\text{CO}_2\text{H}$] and 1,12-dodecanedicarboxylic acids.

Schmitt⁹⁰ claims to have prepared dehydrosqualene,



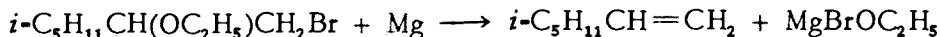
by a Barbier-type reaction involving metallic magnesium, tetramethylene bromide, and pseudoionone (ψ -ionone),



No statement is made concerning the yield.

Pentamethylene and the higher polymethylene halides give fairly satisfactory yields of the dimagnesium compounds, although most workers report considerable Wurtz reaction.⁹¹ Cycloalkane formation appears to be negligible.

As regards their reactions with magnesium the β - and γ -halo ethers have something in common with the analogous dihalides, for it appears that the phenoxy group, at least, may sometimes play the part of a pseudohalogen. Grignard⁹² observed, for example, that β -bromophenotole reacts with magnesium principally to form ethylene and the bromomagnesium salt of phenol, together with a little 1,4-diphenoxybutane. In so far as it proceeds (until halted by occlusion of the magnesium surface), the reaction of β -ethoxyisoheptyl bromide with magnesium is similar.⁹³



The behavior of γ -iodopropoxybenzene is analogous to that of trimethylene bromide in that reaction with magnesium leads chiefly to cyclopro-

⁸⁹ von Braun and Sobecki, *Ber.*, 44, 1918-31 (1911).

⁹⁰ Schmitt, *Ann.*, 547, 115-22 (1941).

⁹¹ See, e.g.: Grignard and Vignon, *Compt. rend.*, 144, 1358-60 (1907); *Chem. Abstr.*, 1, 2553 (1907); von Braun and Sobecki, *Ber.*, 44, 1039-48, 1918-31 (1911); Hilpert and Grüttner, *Ber.*, 47, 177-85 (1914); Dionneau, *Ann. chim.*, [9], 3, 194-268 (1915); Grüttner and Wiernik, *Ber.*, 48, 1473-86 (1915); Grüttner and Krause, *Ber.*, 49, 2666-75 (1916); Lespieau, *Compt. rend.*, 187, 605-7 (1928); *Chem. Abstr.*, 23, 817 (1929); *Bull. soc. chim.*, [4], 43, 1189-93 (1928); Müller and Schutz, *Ber.*, 71B, 689-91 (1938); Lukeš and Bláha, *Chem. Listy*, 46, 683-4 (1952); *Chem. Abstr.*, 47, 8013 (1953).

⁹² Grignard, *Compt. rend.*, 138, 1048-50 (1904); *J. Chem. Soc.*, 86, 1, 494 (1904).

⁹³ Swallen and Boord, *J. Am. Chem. Soc.*, 52, 651-60 (1930).

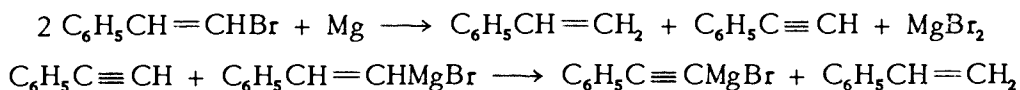
From the results of iodine titration, Kirrman¹⁰¹ obtained very little evidence of the Grignardization of either 1-bromo- or 2-bromo-1-heptene. Carbonation of the reaction mixtures apparently gave rise to some acidic products, but no pure acids were isolated.

Apparently, however, the substituted vinyl halides are somewhat more amenable to Grignardization than is vinyl bromide itself, for successful preparations with isobutenyl bromide and α -methylisobutenyl bromide are reported by Krestinsky (*loc. cit.*¹⁰⁰). There is, however, evidence of a considerable amount of side-reaction, as the following examples¹⁰² show.

- (1) $(\text{CH}_3)_2\text{C}=\text{CHBr}$ (195 g.) + Mg (37 g.) + CH_3CHO (100 g.) \longrightarrow
 $i\text{-C}_4\text{H}_8$ (8 l.) + $\text{C}_2\text{H}_5\text{OH}$ (12 g.) + $(\text{CH}_3)_2\text{C}=\text{CHCH}(\text{OH})\text{CH}_3$ (20 g.) +
 $(\text{CH}_3)_2\text{C}=\text{CHCH}(\text{O}_2\text{CCH}_3)\text{CH}_3$ + $(\text{CH}_3)_2\text{C}=\text{CHCH}=\text{CH}_2$
- (2) $(\text{CH}_3)_2\text{C}=\text{CHBr}$ (165 g.) + Mg (29 g.) + $i\text{-C}_3\text{H}_7\text{CHO}$ (88 g.) \longrightarrow
 $i\text{-C}_4\text{H}_8$ + $i\text{-C}_4\text{H}_9\text{OH}$ (8 g.) + $(\text{CH}_3)_2\text{C}=\text{CHCH}(\text{OH})\text{-}i\text{-C}_3\text{H}_7$ (22 g.) +
 $(\text{CH}_3)_2\text{C}=\text{CHCH}=\text{C}(\text{CH}_3)_2$ + other products

The *isobutenyl* of example 2 might reasonably be attributed, in part at least, to Wurtz reaction, but it would seem that the 4-methyl-1,3-pentadiene of example 1 must be the dehydrate of the "normal" product.

Tiffeneau¹⁰³ treated styryl bromide with magnesium, and, after hydrolysis of the reaction mixture, isolated styrene, bistyryl, and phenylacetylene. Carbonation and subsequent acidification of a similar reaction mixture yielded both cinnamic and phenylpropionic acids. The Grignard reagent from which the phenylpropionic acid must have been derived is attributed to the reactions:



Tiffeneau (*loc. cit.*¹⁰³) was also successful in preparing a Grignard reagent from β -methylstyryl bromide. The preparations and reactions of other vinyl Grignard reagents have been described by (*inter alios*): Ziegler and Ochs,¹⁰⁴ Hurd and Webb,¹⁰⁵ Koelsch,¹⁰⁶ Smith and Sprung,¹⁰⁷ and Tsatsas.¹⁰⁸

¹⁰¹ Kirrman, *Compt. rend.*, 184, 1178-9 (1927); *Chem. Zentr.*, 1927, II, 236.

¹⁰² Krestinsky, (a) *Ber.*, 55B, 2754-62 (1922); (b) *ibid.*, 55B, 2762-70 (1922).

¹⁰³ Tiffeneau, *Compt. rend.*, 135, 1346-8 (1902); *J. Chem. Soc.*, 84, I, 241 (1903). See also: Meyer and Schuster, *Ber.*, 55B, 815-9 (1922); Rupe and Proske, *Ber.*, 43, 1231-4 (1910).

¹⁰⁴ Ziegler and Ochs, *Ber.*, 55B, 2257-77 (1922).

¹⁰⁵ Hurd and Webb, *J. Am. Chem. Soc.*, 49, 546-59 (1927).

¹⁰⁶ Koelsch, (a) *J. Am. Chem. Soc.*, 54, 2045-8 (1932); (b) *ibid.*, 54, 2487-93 (1932); (c) *ibid.*, 54, 3384-9 (1932).

¹⁰⁷ Smith and Sprung, *J. Am. Chem. Soc.*, 65, 1276-83 (1943).

¹⁰⁸ Tsatsas, *Compt. rend.*, 220, 662-4 (1945); *Chem. Abstr.*, 40, 4699 (1946); *Ann. chim.*, [12], 1, 342-94 (1946).

Reported attempts to prepare organomagnesium fluorides have been uniformly unsuccessful. Swarts¹⁰⁹ found that amyl fluoride reacts very slowly with iodine-activated magnesium. After one hundred hours reflux in ethyl ether the identified products were decane and magnesium fluoride. According to Gilman and Heck,¹¹⁰ a small amount of biphenyl is formed when fluorobenzene is heated with magnesium for two hundred hours at 300°. When fluorobenzene is sealed in a tube with iodine-activated magnesium-copper alloy, the mixture gives no color test with Michler's ketone at the end of six months; at the end of eighteen months the color test is positive. Bernstein *et al.*¹¹¹ made various attempts to prepare a Grignard reagent from benzyl fluoride, including one in which the halide was sealed in a tube with ethyl ether and heated at 100° for ten days. The only product obtained was a little bibenzyl.

Among other halides that have been reported as resisting Grignardization are: 2-bromofluorene, 3-bromoacenaphthene;¹¹² 2-iodothiazole;¹¹³ 1-chloro-1,1-diphenylethane;¹¹⁴ and 4-bromododecane.¹¹⁵ Conceivably some, at least, of these might yield to sufficiently adroit manipulation.

GRIGNARD REAGENT PREPARATION BY "ENTRAINMENT"

The method of "entrainment," or continuous activation was introduced by Grignard¹¹⁶ to effect the preparation of organomagnesium halides from organic halides that do not yield to the ordinary methods of activation, or that give very poor yields under ordinary conditions. It consists essentially in the treatment of an excess of metallic magnesium with an ethereal solution of a mixture of halides comprising one equivalent of the halide corresponding to the desired Grignard reagent and one or more equivalents of a halide that reacts readily with magnesium (suitably ethyl bromide).

From Grignard's original note (*loc. cit.*¹¹⁶), a note by Clément,¹¹⁷ who collaborated in the original work, and a later note by Grignard,¹¹⁸ one might gather that carbonation of a Grignard solution of pentamethylphenylmagnesium bromide, prepared with the aid of one equivalent of ethyl bromide, leads to an 80-82 percent overall yield of pentamethyl-

¹⁰⁹Swarts, *Bull. soc. chim. Belg.*, 30, 302-15 (1921).

¹¹⁰Gilman and Heck, *J. Am. Chem. Soc.*, 53, 377-8 (1931).

¹¹¹Bernstein, Roth, and Miller, *J. Am. Chem. Soc.*, 70, 2310-4 (1948).

¹¹²Miller and Bachman, *J. Am. Chem. Soc.*, 57, 766-71 (1935).

¹¹³Travagli, *Gazz. chim. ital.*, 78, 592-9 (1948); *Chem. Abstr.*, 43, 2615 (1949).

¹¹⁴Brown, Mighton, and Senkus, *J. Org. Chem.*, 3, 62-75 (1938).

¹¹⁵Petrov and Ol'dekop, *J. Gen. Chem. (U.S.S.R.)*, 18, 859-64 (1948); *Chem. Abstr.*, 43, 107 (1949).

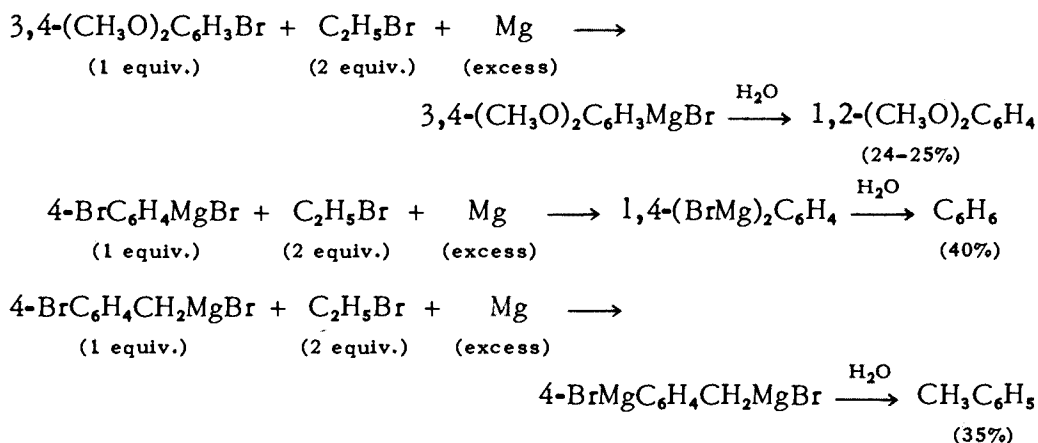
¹¹⁶Grignard, *Compt. rend.*, 198, 625-8 (1934).

¹¹⁷Clément, *Compt. rend.*, 198, 665-7 (1934).

¹¹⁸Grignard, *Compt. rend.*, 198, 2217-20 (1934).

benzoic acid. However, an expanded article by Clément,¹¹⁹ together with an article by Savard and Hösöğüt,¹²⁰ makes it appear that this yield must have been based on the amount of pentamethylphenylmagnesium bromide present (40–60 percent on the basis of the bromide expended), leading to an overall 36–49 percent yield of acid.

The yields of other organomagnesium halides, prepared with the aid of other collaborators, and reported in Grignard's original note, as determined by hydrolysis, appear to be more in line with reasonable expectation.



According to Clément (*loc. cit.*¹¹⁷), optimum results in the ethyl bromide "entrainment" preparation of pentamethylphenylmagnesium bromide are obtained by the use of at least one equivalent of ethyl bromide per equivalent of pentamethylbromobenzene in a dilution of about one liter of ether per mole of bromide mixture, and with the use of magnesium in about 25 percent excess.

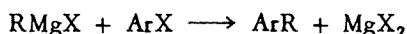
In his later article Clément (*loc. cit.*¹¹⁹) reports that, in the preparation of pentamethylphenylmagnesium bromide with the aid of ethyl bromide, yields vary from 40–60 percent depending upon the experimental conditions (concentration of ethereal solution, temperature of reaction, rate of introduction of "entrainer"). Yields also vary with the "entrainer" used, attaining 80–90 percent with methyl bromide. Clément found that replacement of ethyl bromide with ethyl iodide did not materially affect the yield. He also used allyl bromide and allyl iodide successfully.

The principal competitor of Grignard reagent formation appears to be an unsymmetrical Wurtz reaction.* According to one example reported by

¹¹⁹Clément, *Ann. chim.*, [11], 13, 243–316 (1940).

¹²⁰Savard and Hösöğüt, *Rev. faculté sci. univ. Istanbul*, [N.S.], 3, 164–73 (1938); *Chem. Abstr.*, 32, 5795 (1938).

*It may be noted that, in general, Grignard reactions of the type

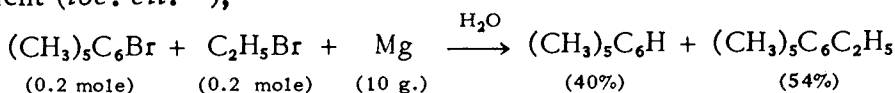


do not take place, and that, as a rule, Grignard reactions of the type



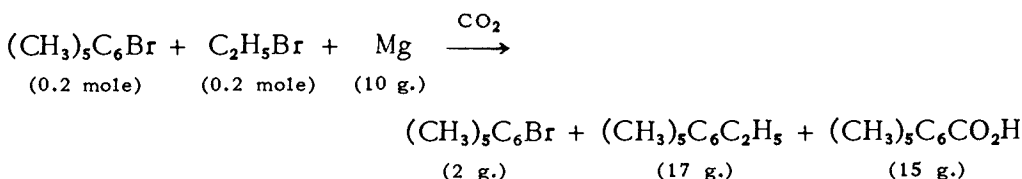
give poor, if any, yields under the usual conditions of Grignard reagent preparation.

Clément (*loc. cit.*¹¹⁹),



When methyl bromide (or iodide) is used under similar conditions the Wurtz reaction takes place to the extent of only 10–20 percent.

The foregoing example of Clément falls in line with several given by Savard and Hösoğüt (*loc. cit.*¹²⁰), of which the following may serve as illustrative:



The preparative procedures reported vary somewhat in detail, but the following description by Mann and Watson¹²¹ is fairly representative. "A round-bottomed flask of 1-liter capacity was fitted with a reflux water-condenser, stirrer, dropping-funnel, and an inlet-tube through which a current of nitrogen could be passed throughout the experiment; the necks of this condenser and dropping-funnel were closed with calcium chloride tubes. Magnesium turnings (15 g.) were placed in the flask, and a solution of ethyl bromide (1 ml., 0.02 mole) in ether (50 ml.) [was] added. A crystal of iodine was also added to initiate the reaction. When the ether was boiling, the stirrer was started, and a solution of pure, dry 2-bromopyridine (28.8 ml., 0.49 mole) and ethyl bromide (10.5 ml., 0.23 mole) in ether (250 ml.) was run in at such a rate that gentle boiling continued. The addition required seventy-five minutes, and the formation of the Grignard reagent was then completed by refluxing the mixture for a further two hours."

References to several other exemplary preparations are assembled in Table II-VIII.

Urion¹²² has suggested that the "entrainment" method of preparation constitutes an example of functional exchange of the type $\text{RMgBr} + \text{R}'\text{Br} \longrightarrow \text{R}'\text{MgBr} + \text{RBr}$. In support of his hypothesis, Urion combined approximately equimolecular quantities of cyclohexyl bromide and ethylmagnesium bromide, allowed the mixture to stand for twenty-four hours, and obtained, upon hydrolysis, a 12 percent yield of cyclohexane. Removal of ether by distillation from a mixture similarly prepared was reported to increase the yield of cyclohexane to 40 percent. An equimolecular mixture of 4-bromophenylmagnesium bromide and ethylmagnesium bromide from which the ether had been partially removed by distillation yielded, upon hydrolysis, 15 percent of benzene.

¹²¹Mann and Watson, *J. Org. Chem.*, 13, 502–31 (1948).

¹²²Urion, *Compt. rend.*, 198, 1244–6 (1934).

SOME REPRESENTATIVE GRIGNARD REAGENT PREPARATIONS BY THE METHOD OF "ENTRAINMENT"

Halide, RX (corresponding to RMgX)	"Entrainer," R'X'	Co-reactant	Yield, "Normal" Product (%)	Ref.
2-Bromopyridine	C ₂ H ₅ Br	AsCl ₃	ca. 80 (crude)	3
2-Bromopyridine	C ₂ H ₅ Br	PCl ₃	33	3
2-Bromopyridine	C ₂ H ₅ Br	C ₆ H ₅ CHO	49	11
2-Bromopyridine	C ₂ H ₅ Br	4-BrC ₆ H ₄ (C ₆ H ₅)PCl	(?)*	3
2-Bromopyridine	C ₂ H ₅ Br	C ₆ H ₅ AsCl ₂	10	10
2-Bromopyridine	C ₂ H ₅ Br	C ₆ H ₅ PCl ₂	(?)*	10
2-Bromopyridine	C ₂ H ₅ Br	(C ₆ H ₅) ₂ AsCl	4	10
2-Bromopyridine	C ₂ H ₅ Br	(C ₆ H ₅) ₂ PCl	20	10
3-Bromopyridine	C ₂ H ₅ Br	4-BrC ₆ H ₄ (C ₆ H ₅)PCl	(?)*	3
Chlorobenzene	C ₂ H ₅ Br	CO ₂	39	7
2,5-Dimethyl-3-iodothiophene	C ₂ H ₅ Br	CO ₂	40	15
1-Bromo-2-methoxymethylbenzene	C ₂ H ₅ Br	(CH ₂) ₂ O	53	6
1-Bromo-3,4-dimethoxybenzene	C ₂ H ₅ Br	H ₂ O	18	7
4-Bromodimethylaniline	C ₂ H ₅ Br	4-BrC ₆ H ₄ (C ₆ H ₅)PCl	37 [†]	3
C ₈ H ₁₇ Cl [‡]	C ₂ H ₅ Br	CO ₂	34	16
1-Bromomethyl-2-β-bromoethylbenzene	C ₂ H ₅ Br	CO ₂	(?)*	6
4-Bromohemimellitene [¶]	C ₂ H ₅ Br	(CH ₂) ₂ O	(?)*	14
1-Bromo-2-ethoxymethylbenzene	C ₂ H ₅ Br	(CH ₂) ₂ O	35	5
1-C ₁₀ H ₇ Cl	C ₂ H ₅ Br	CO ₂	16	7
1-C ₁₀ H ₇ Cl	C ₂ H ₅ Br	H ₂ O	46	7

* The "normal" product was obtained, but the yield is not stated.

[†] Fifteen to twenty percent of the halide used was recovered as dimethylaniline.

[‡] The halide employed is "diisobutylene hydrochloride"; the acid recovered is neopentylidimethylacetic, *t*-C₄H₉CH₂C(CH₃)₂CO₂H.

[§] Thirteen and nine-tenths grams of the dibromide yielded 1.4 g. of a white solid, C₂₀H₂₂O₄, and 3.9 g. of *o*-ethylphenylacetic acid, 2-C₂H₅C₆H₄CH₂CO₂H.

[¶] 1-Bromo-2,3,4-trimethylbenzene.

TABLE II-VIII (Continued)

Halide, RX (corresponding to RMgX)	"Entrainer," R'X'	Co-reactant	Yield, "Normal" Product (%)	Ref.
1-Methoxymethyl- 2- β -chloroethylbenzene	C ₂ H ₅ Br	CO ₂	58	6
Duryl bromide [†]	C ₂ H ₅ Br	3,4,5-(CH ₃ O) ₃ C ₆ H ₂ COC1	16	4
1-Bromo-4-methylnaphthalene	CH ₃ I	(CH ₂) ₅ CO	50**	1
2-Bromo-6-methoxynaphthalene	CH ₃ I	CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅	(?)*	12
2-Bromo-6-methoxynaphthalene	C ₂ H ₅ Br	1-Methyl-2-piperidone	15	9
2-Bromo-6-methoxynaphthalene	C ₂ H ₅ Br	CO ₂	50	21
2-Bromo-6-methoxynaphthalene	C ₂ H ₅ Br	CO ₂	33	22
1-Iodo-6-methoxynaphthalene	C ₂ H ₅	HCHO	80	2
Bromopentamethylbenzene	C ₂ H ₅ Br	HCO ₂ C ₂ H ₅	9††	8
1-Bromo-2,4,5-trimethyl- 3,6-dimethoxybenzene	C ₂ H ₅ Br	CO ₂	71	17
1-Bromo-2,4,5-trimethyl- 3,6-dimethoxybenzene	C ₂ H ₅ Br	(CH ₂) ₂ O	62	17
3-Iodoacenaphthene	C ₂ H ₅ Br	(CH ₂) ₂ O	55	18
1-Bromo-3,4-dimethyl- naphthalene	CH ₃ I	(CH ₂) ₅ CO	64**	1
2,2,5,7,8-Pentamethyl- 6-bromochroman	C ₂ H ₅ Br	O ₂	8	13
9-Bromo-10-phenylanthracene	C ₂ H ₅ Br	CO ₂	40	19
9,10-Di-(<i>p</i> -bromophenyl)- anthracene	CH ₃ I	CO ₂	(?)*	20

[†]1-Bromo-2,3,5,6-tetramethylbenzene.

** The product isolated is the hydrocarbon (*i.e.*, the dehydrate of the "normal" addition product).

†† About 13 percent of dipentamethylphenylmethane was also isolated.

REFERENCES FOR TABLE II-VIII

- (1) Bergmann and Szmuszkowicz, *J. Am. Chem. Soc.*, 69, 1367-70 (1947).
- (2) Billeter and Miescher, *Helv. Chim. Acta*, 29, 859-71 (1946).
- (3) Davies and Mann, *J. Chem. Soc.*, 1944, 276-83.
- (4) Fuson and Gaertner, *J. Org. Chem.*, 13, 496-501 (1948).
- (5) Holliman and Mann, *J. Chem. Soc.*, 1942, 737-41.
- (6) Holliman and Mann, *J. Chem. Soc.*, 1947, 1634-42.
- (7) Jezierski, *Roczniki Chem.*, 20, 47-53 (1946); *Chem. Abstr.*, 42, 1910 (1948).
- (8) Lapkin, *J. Gen. Chem. (U.S.S.R.)*, 16, 729-34 (1946); *Chem. Abstr.*, 41, 1218 (1947).
- (9) Lee, Ziering, Berger, and Heineman, *Jubilee Vol. Emil Barends*, 1946, 264-305; *Chem. Abstr.*, 41, 6246 (1947).
- (10) Mann and Watson, *J. Org. Chem.*, 13, 502-31 (1948).
- (11) Overhoff and Proost, *Rec. trav. chim.*, 57, 179-84 (1938).
- (12) Robinson and Slater, *J. Chem. Soc.*, 1941, 376-85.
- (13) Smith, U. S. Patent 2,397,212, Jan. 7, 1943; *Chem. Abstr.*, P3573 (1946).
- (14) Smith and Agre, *J. Am. Chem. Soc.*, 60, 648-52 (1938).
- (15) Steinkopf, Poulsson, and Herdey, *Ann.*, 536, 128-34 (1938).
- (16) Whitmore, Wheeler, and Surmatis, *J. Am. Chem. Soc.*, 63, 3237 (1941).
- (17) Smith, Wawzonek, and Miller, *J. Org. Chem.*, 6, 229-35 (1941); Smith and Miller, *J. Am. Chem. Soc.*, 64, 440-5 (1942).
- (18) Cook, Haslewood, and Robinson, *J. Chem. Soc.*, 1935, 667-71.
- (19) Dufraisse, Velluz, and Velluz, *Bull. soc. chim.*, [5], 4, 1260-4 (1937).
- (20) Dufraisse and Margoulis-Molho, *Bull. soc. chim.*, [5], 7, 930-3 (1940).
- (21) Fries and Schimmelschmidt, *Ber.*, 58B, 2835-45 (1925).
- (22) Hudson, *J. Chem. Soc.*, 1946, 76-8.

However, an earlier study by Gilman and Jones,¹²³ a note by Grignard (*loc. cit.*¹¹⁸), and a more recent study by Kharasch and Fuchs¹²⁴ rather conclusively disprove the generality of functional exchange of the type envisioned by Urien, and cast some doubt on the specific examples cited by him.

Gilman and Jones (*loc. cit.*¹²³) submitted to three-hour reflux ether-benzene or ether-toluene solutions of equimolecular mixtures of bromobenzene and benzylmagnesium chloride, of benzyl chloride and phenylmagnesium bromide, of bromobenzene and triphenylmethylmagnesium chloride, of triphenylmethyl chloride and phenylmagnesium bromide, and of triphenylmethyl chloride and benzylmagnesium chloride, respectively. Upon conclusion of the reflux, the solutions were cooled and carbonated. In no case was any carboxylic acid other than that corresponding to the Grignard reagent originally present isolated.

As Grignard (*loc. cit.*¹¹⁸) has pointed out, the yield of benzene (15 percent), from the dimagnesium Grignard compound of *p*-dibromobenzene, obtained by Urien does not differ greatly from the yield (12.8 percent) obtained by Quelet¹²⁵ through the treatment of an excess of magnesium with

¹²³ Gilman and Jones, *J. Am. Chem. Soc.*, 51, 2840-3 (1929).

¹²⁴ Kharasch and Fuchs, *J. Org. Chem.*, 10, 292-7 (1945).

¹²⁵ Quelet, *Bull. soc. chim.*, [4], 41, 933-6 (1927).

p-dibromobenzene in the conventional manner. Grignard further showed that the yields of 3,4-dimethoxyphenylmagnesium bromide, of pentamethylphenylmagnesium bromide and of the dimagnesium Grignard compounds of *p*-dibromobenzene and *p*-bromobenzyl bromide obtainable by the method of "entrainment" are all materially greater than the corresponding yields obtainable by one or more of three variations of Urien's method.

It has been found in the laboratories of the University of Chicago¹²⁴ that a mixture of ethylmagnesium bromide and cyclohexyl bromide, on heating, evolves ethane, ethylene, cyclohexane and cyclohexene. It is possible that in his second experiment, Urien failed to detect ethane and ethylene and mistook a mixture of cyclohexane (b. 81.4°) and cyclohexene (b. 83°) for cyclohexane.

Kharasch and Fuchs (*loc. cit.*¹²⁴) could detect no functional exchange between *n*-butylmagnesium bromide and bromobenzene, *n*-butylmagnesium bromide and *p*-bromoanisole, *n*-butylmagnesium bromide and triphenylvinyl bromide, methylmagnesium bromide and *p*-biphenyl bromide, methylmagnesium bromide and 9-chlorofluorene, or phenylmagnesium bromide and *n*-butyl bromide, although some of these and other Grignard-halide pairs did undergo exchange when cobaltous chloride was added to the mixture.

On the whole the available evidence suggests that functional exchange (*q.v.*) is probably in most cases a free-radical reaction that may be initiated by the presence of certain metallic impurities in the magnesium used, by the presence of magnesian halides, or by one of several other reaction factors that could give rise to free radicals.

Grignard's¹¹⁸ interpretation of the efficacy of the "entrainment" method of preparation assumes the formation of a relatively ether-soluble complex of the type $C_2H_5MgBr \cdot RMgBr \cdot n(C_2H_5)_2O$. In view of the fact that magnesium bromide has been shown to be much more soluble in ethereal *n*-butylmagnesium bromide solutions than in ether,¹²⁶ it does not appear altogether implausible that a relatively ether-insoluble Grignard reagent might be more ether-soluble in the presence of a relatively ether-soluble Grignard reagent. Whatever the detailed mechanics of the process there is no doubt that many of the Grignard reagents preparable by the "entrainment" method are relatively ether-insoluble and might be expected to form an impervious coating on a magnesium surface, and that the overall effect of the presence of the auxiliary halide ("entrainer") is a continuous cleansing of the surface.

There is, however, another aspect of the phenomenon that should not be entirely overlooked. There would seem to be some reason to believe that the Grignard reagent formation reaction is, in a sense, self-activating. A possible explanation of this effect (if it be real) is that even a comparatively clean magnesium surface has relatively few points of unsatura-

¹²⁶ Doering and Noller, *J. Am. Chem. Soc.*, 61, 3436 (1939).

tion at which reaction with an organic halide may take place. Reaction at any one of these points, and diffusion into solution of the Grignard reagent formed, probably increases the number of points of unsaturation and so facilitates further reaction. Such an effect might be expected to be especially significant in the cases of such relatively unreactive halides as chlorobenzene and 1-chloronaphthalene.

PREPARATION OF GRIGNARD REAGENTS IN SOLVENTS OTHER THAN ETHYL ETHER¹²⁷

Ethers other than ethyl ether. Unsuccessful in attempts to prepare organomagnesium halides in "neutral" solvents such as benzene or ligroin, Grignard (*loc. cit.*¹) attributed peculiar significance to the constitution of ethyl ether as a reaction medium and investigated the suitability of other ethers, specifically, methyl isoamyl ether and anisole, which he pronounced satisfactory.

Tschugaeff¹²⁸ suggested the use of ethereal methylmagnesium iodide as a reagent for the quantitative evaluation of hydroxyl groups in organic compounds by measurement of the volume of methane evolved in the reaction:



The variability of the vapor pressure of ethyl ether with temperature, however, introduced considerable errors into the method as originally proposed. These Hibbert and Sudborough¹²⁹ sought to eliminate by substituting amyl ether for ethyl ether as a solvent. To 6.09 g. of magnesium covered with 100 ml. of thoroughly dried amyl ether, they introduced 35.5 g. of methyl iodide dissolved in 20 ml. of dry amyl ether. Reaction was initiated by gentle warming on a sand-bath and was then allowed to proceed spontaneously, being completed ultimately by a half-hour of heating. The solution was then decanted from residual magnesium and made up to 200 ml. with dry amyl ether.

Senier *et al.*¹³⁰ made use of mixtures of ethyl ether with less volatile ethers, such as anisole and phenetole, in their investigation of acridine-Grignard reagent addition products.

In a series of studies, in which he generalized the Tschugaeff method for the determination of "active" hydrogen, Zerewitinoff¹³¹ followed the

¹²⁷Early work in this field has been reviewed by Gilman and McCracken, *Rec. trav. chim.*, 46, 463-72 (1927).

¹²⁸Tschugaeff, *Ber.*, 35, 3912-4 (1902).

¹²⁹Hibbert and Sudborough, *Proc. Chem. Soc.*, 19, 285-6 (1903); *J. Chem. Soc.*, 1904, 933-8 (1904).

¹³⁰Senier, Austin, and Clarke, *J. Chem. Soc.*, 87, 1469-74 (1905).

¹³¹Zerewitinoff, *Ber.*, 40, 2023-31 (1907); 41, 2233-43, 2244-5 (1908); 43, 1490-5 (1910); 45, 2384-9 (1912); 47, 1659, 2417-23 (1914); *Z. anal. Chem.*, 50, 680-91 (1911); *Chem. Abstr.*, 6, 203 (1912); *Z. anal. Chem.*, 52, 729-37 (1914); *Chem. Abstr.*, 8, 2074 (1914).

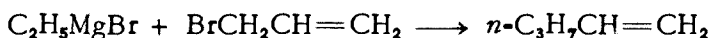
Lead of Hibbert and Sudborough in adopting amyl ether as a solvent. His amyl ether solutions were prepared by combining 9.6 g. of magnesium with 35.5 g. of methyl iodide and a few iodine crystals in 100 ml. of sodium-dried amyl ether. Reaction began spontaneously and was encouraged, if necessary, by gentle warming, being completed eventually by one to two hours heating on a boiling water-bath.

Sudborough and Hibbert¹³² have also used phenetole as a solvent in "active" hydrogen determinations. To 6.09 g. of magnesium in 120 ml. of phenetole, they added a solution of 35.5 g. of methyl iodide in 20 ml. of phenetole. The mixture was warmed for forty-five minutes on a sand-bath, and was finally boiled for thirty minutes to expel residual methyl iodide.

Other references to the use of high-boiling ethers in Tschugaeff-Zerewitinoff determinations may be found in Chapter XVIII.

Bourgom,¹³³ who prepared *n*-butylmagnesium bromide in methylal $[(\text{CH}_3\text{O})_2\text{CH}_2]$, found that the reaction tended to slow down and eventually stop (due to Grignard reagent insolubility) when a ratio of two moles of bromide to 500 ml. of methylal was used, but proceeded satisfactorily with one mole of bromide to 500 ml. of methylal.

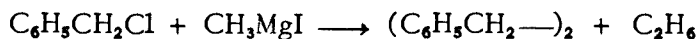
Because of the difficulty of separating 1-pentene (b. 40°) from ethyl ether, Kirmann¹³⁴ used *n*-propyl ether (b. 91°) in carrying out the reaction



obtaining a 94 percent yield of the olefin.

In an investigation of the oxygen-induced luminescence of Grignard reagent solutions, Evans and Diepenhorst¹³⁵ prepared over ninety Grignard reagents in a variety of solvents, including some seventeen ethers. No details of their preparations are described, save that they were carried out in sealed Pyrex tubes, with iodine and *n*-butyl bromide as the principal activators employed.

Fuson¹³⁶ attempted to evade the difficulties introduced by ethyl ether vapor into measurement of the volume of gases evolved in coupling reactions by employing isoamyl ether as a reaction medium, but reported that the reaction



does not take place in the latter solvent.

In the belief that *n*-butyl ether might profitably be substituted for the lower-boiling, more volatile and more inflammable ethyl ether in many

¹³²Sudborough and Hibbert, *J. Chem. Soc.*, 95, 477-80 (1909); Hibbert, *ibid.*, 101, 328-41 (1912).

¹³³Bourgom, *Bull. soc. chim. Belg.*, 33, 101-15 (1924).

¹³⁴Kirmann, *Bull. soc. chim.*, [4], 39, 988-91 (1926).

¹³⁵Evans and Diepenhorst, *J. Am. Chem. Soc.*, 48, 715-23 (1926).

¹³⁶Fuson, *J. Am. Chem. Soc.*, 48, 2681-9 (1926).

Grignard reactions, Marvel *et al.*,¹³⁷ prepared several Grignard reagents in the former solvent and estimated the percentage yields by titration.

The preparations are described substantially as follows. In a flask were placed about 40 ml. of *n*-butyl ether, 1.5 g. of magnesium turnings and a crystal of iodine. The theoretical equivalent of halide, dissolved in enough *n*-butyl ether to make a total volume of 30 ml. was placed in a separatory funnel. A small amount of the halide solution was added, and reaction was initiated by warming. The temperature necessary varied somewhat with the individual halide. When reaction had begun, the remainder of the halide solution was added, with stirring, at a rate that allowed reaction to proceed smoothly. After completion of the addition, stirring was continued until the mixture had cooled to room temperature.

Minimum and maximum yields obtained in multiple experiments are recorded in Table II-IX.

TABLE II-IX

PREPARATION OF GRIGNARD REAGENTS IN *n*-BUTYL ETHER

Halide	Yield RMgBr (%)	Halide	Yield RMgBr (%)
C ₂ H ₅ Br	91-93	C ₆ H ₅ Br	70-77
<i>n</i> -C ₃ H ₇ Br	89-90	(CH ₂) ₅ CHBr	80-83
<i>i</i> -C ₃ H ₇ Br	79-80	<i>n</i> -C ₇ H ₁₅ Br	73-81
<i>n</i> -C ₄ H ₉ Br	86-87	C ₆ H ₅ CH ₂ CH ₂ Br	68-71
<i>i</i> -C ₄ H ₉ Br	82-86	1-C ₁₀ H ₇ Br	63-71
<i>s</i> -C ₄ H ₉ Br	68-72		

Whitmore *et al.*,¹³⁸ describe the preparation of a *n*-butyl ether solution of *t*-butylmagnesium chloride as follows. "Dry *n*-butyl ether (25 ml.) and 5 ml. of pure *n*-propyl bromide were added to 4 moles of magnesium turnings in the usual apparatus to initiate the reaction. When the reaction started 1 liter of the dry ether containing 5 ml. of *n*-propyl bromide was added. The addition of this relatively large amount of *n*-propyl bromide was necessary to ensure continued reaction. *t*-Butyl chloride (370 g., 4 moles) in 1700 ml. of the ether was added over a period of twenty-four hours; stirring was continued for eighteen hours. The flask was cooled in a stream of running water at 16-18°. The yield was 73%."

Young *et al.*,¹³⁹ have also made use of *n*-butyl ether in the preparation of butenylmagnesium bromide solutions. They observe that, as compared with ethyl ether, butyl ether preparations of organomagnesium halides of this type require higher molar dilutions and more efficient stirring because of the greater tendency toward reaction in the sense:



¹³⁷ Marvel, Blomquist, and Vaughn, *J. Am. Chem. Soc.*, 50, 2810-2 (1928).

¹³⁸ Whitmore, Whitaker, Mosher, Breivik, Wheeler, Miner, Sutherland, Wagner, Clapper, Lewis, Lux, and Popkin, *J. Am. Chem. Soc.*, 63, 643-54 (1941).

¹³⁹ Young, Prater, and Winstein, *J. Am. Chem. Soc.*, 55, 4908-11 (1933).

They recommend a solvent-halide ratio of 38:1 for allyl bromide and of 76:1 for crotyl bromide.

In the experiment which gave the maximum (99 percent) yield of Grignard reagent, 0.42 gram-atom of freshly cut 20-30 mesh (99.5 percent) magnesium turnings was covered with butyl ether. Allyl bromide (0.035 mole), dissolved in the remainder of a total of 1.33 mole of butyl ether was then added gradually, with highly efficient stirring, over a period of three hours.

The optimum crotyl bromide preparation, which gave a quantitative yield of Grignard reagent, was conducted in the same manner, save that twice the relative quantity of butyl ether was used.

Preparations of butenylmagnesium bromide in *n*-propyl ether and in a mixture of 90 percent isopropyl ether and 10 percent ethyl ether are also described.¹⁴⁰

A French patent¹⁴¹ protects the use of methyl amyl, methyl cyclohexyl and methyl benzyl ethers in the preparation of β -substituted ethyl alcohols from ethylene chlorohydrin. In one example described, 14.4 parts of magnesium turnings, 0.1 part of iodine and 25 parts of a solution comprising 94 parts of bromobenzene in 376 parts of methyl amyl ether are combined and warmed to 50° to initiate reaction. The mixture is then cooled to 15-20°, and the remainder of the halide solution is added. When all the metal has disappeared, the resultant Grignard solution is treated with 16 parts of ethylene chlorohydrin with warming. A 95 percent yield of phenethyl alcohol is claimed.

Rathman and Leighty¹⁴² have investigated isopropyl ether as a possible substitute for ethyl ether as a solvent for Grignard reactions, and are inclined to regard it as unsatisfactory. However, from the abstract available, it is not apparent whether or not any attempt was made to eliminate peroxides (for which isopropyl ether is notoriously infamous), nor is it evident that anything approximating optimum reaction conditions was attained.

Hillyer¹⁴³ claims that treatment with potassium permanganate and sodium fails to remove all peroxide from isopropyl ether, and that the product is unsuitable for Grignard reagent preparation, but that isopropyl ether purified with chromic oxide "proved very satisfactory for a Grignard reaction."

¹⁴⁰ Young, Lane, Loshokoff, and Winstein, *J. Am. Chem. Soc.*, 59, 2441-3 (1937).

¹⁴¹ I. G. Farbenindustrie Akt.-Ges., French Patent, 682,142, May 23, 1930; *Chem. Zentr.*, 1930, II, 3082.

¹⁴² Rathman and Leighty, *Trans. Illinois State Acad. Sci.*, 24, 312-5 (1931); *Chem. Abstr.*, 26, 2167 (1932).

¹⁴³ Hillyer, U. S. Patent 2,380,524, July 31, 1945; *Chem. Abstr.*, 39, P5465 (1945).

Tarbell and Paulson¹⁴⁴ have prepared phenylmagnesium bromide in (+)-2-methoxybutane with a view to the possibility of effecting an induced asymmetric synthesis by treating the Grignard reagent with acetaldehyde. (Incidentally, the product obtained was the racemic secondary alcohol.)

Carlin and Smith¹⁴⁵ have found that, although 1,3-dioxane behaves similarly to 1,4-dioxane as a precipitant of RMgX and MgX_2 , 4-methyl-1,3-dioxane is suitable for use as a solvent in the preparation and reaction of Grignard reagents. Using a procedure somewhat similar to that employed by Marvel *et al.* (*loc. cit.*¹³⁷) in the preparation of *n*-butyl ether Grignard solutions, they prepared several Grignard reagents in the yields indicated in Table II-X. No ether cleavage was detected.

TABLE II-X

PREPARATION OF GRIGNARD REAGENTS IN 4-METHYL-1,3-DIOXANE

Halide	Yield RMgX (%)	Halide	Yield RMgX (%)
$\text{C}_2\text{H}_5\text{Br}$	92-93	$t\text{-C}_4\text{H}_9\text{Cl}$	63
$n\text{-C}_3\text{H}_7\text{Br}$	90-92	$(\text{CH}_2)_5\text{CHBr}$	86-87
$i\text{-C}_3\text{H}_7\text{Br}$	81-88	$n\text{-C}_7\text{H}_{15}\text{Br}$	88-89
$n\text{-C}_4\text{H}_9\text{Br}$	92-93	$\text{C}_6\text{H}_5\text{Br}$	81-86
$i\text{-C}_4\text{H}_9\text{Br}$	88-89	$\text{C}_6\text{H}_5\text{CH}=\text{CHBr}$	58-62
$s\text{-C}_4\text{H}_9\text{Br}$	83-86	$1\text{-C}_{10}\text{H}_7\text{Br}$	76

The lower alkyl halides reacted spontaneously; cyclohexyl and *n*-heptyl bromides required brief heating to initiate reaction; solutions of the aromatic bromides and β -bromostyrene required continuous boiling.

Tertiary amines. Tschelinzeff,¹⁴⁶ remarked the similarity between the reactions of Grignard reagents with many oxygen compounds, on the one hand, and their nitrogen analogs, on the other hand, *e.g.*, water and ammonia, alcohols and amines (primary and secondary), ketones and nitriles, esters and amides. From this he reasoned that the nitrogen analog of an ether (*i.e.*, a tertiary amine) might well play the same rôle as an ether in the preparation of a Grignard reagent. For an experimental test of his hypothesis, he selected dimethylaniline, and, in two moles of the solvent, treated one gram-atom of magnesium (activated with a crystal of iodine) with one mole of ethyl iodide. The resultant Grignard solution reacted with benzaldehyde to give a 62 percent yield of ethylphenylmethanol, and with acetophenone to give a 50-60 percent yield of methylethylphenylmethanol, together with 12.5-15.0 percent of the corresponding dehydration product.

Betti and Lucchi¹⁴⁷ have prepared methylmagnesium iodide and phenylmagnesium bromide in *N,N*-dimethylbornylamine (details of method, and yields obtained, not stated in the available abstract).

¹⁴⁴ Tarbell and Paulson, *J. Am. Chem. Soc.*, 64, 2842-4 (1942).

¹⁴⁵ Carlin and Smith, *J. Am. Chem. Soc.*, 69, 2007-8 (1947).

¹⁴⁶ Tschelinzeff, *Ber.*, 37, 2081-5 (1904).

¹⁴⁷ Betti and Lucchi, *Boll. sci. facolta chim. ind., Bologna*, 1940, No. 1-2, 2-5; *Chem. Abstr.*, 34, 2354 (1940).

By private communication from Dr. W. G. Brown (The University of Chicago), the authors are advised that the *N*-alkylmorpholines, which have proved excellent media for lithium aluminum hydride reactions, are also highly satisfactory both for the preparation and subsequent reactions of Grignard reagents.

Hydrocarbons. As has already been noted, Grignard (*loc. cit.*¹⁴⁸) reported failure in attempts to prepare organomagnesium halides in "neutral" solvents such as benzene and ligroïn.

Malmgren¹⁴⁸ obtained no reaction between magnesium and α -camphoryl bromide at water-bath temperature; vigorous reaction set in at 120°, but produced only tar. He also obtained no reaction in boiling benzene, but found that reaction proceeded smoothly in boiling toluene or xylene. Reaction also took place in ethyl ether. In each case, however, there was considerable Wurtz reaction as well as Grignard reagent formation.

Tschelinzeff¹⁴⁹ attempted the preparation of Grignard reagents from a series of iodides (not specified) in benzene, both thiophene-free and thiophene-contaminated, but noted no perceptible reaction after forty-eight hours at the boiling point. In xylene, he was able to prepare Grignard reagents from ethyl, *n*-propyl, *n*-butyl and *n*-amyl iodides without the use of a "catalyst."

When a few drops of a tertiary amine (suitably dimethylaniline) was added, such preparations could be carried out in benzene, toluene, xylene, hexane, petroleum ether, benzine, and terpenoid hydrocarbons. Reaction often began spontaneously, but could always be initiated by warming to 30-40°, or by adding a crystal of iodine. Moderative cooling to control the reaction was sometimes desirable. Reaction was ultimately completed by steam-bath warming. In one experiment described, 0.2 mole of ethyl iodide, 0.2 gram-atom of magnesium, and 0.01 mole of dimethylaniline were combined in benzene. Treatment of the resultant Grignard reagent solution with 0.2 mole of benzaldehyde gave ethylphenylmethanol in 78 percent yield.

Similar tertiary amine-promoted Grignard reagent preparations in hydrocarbon solvents are described by Tschelinzeff,¹⁵⁰ by Stadnikoff¹⁵¹ and by Hess and Rheinboldt.¹⁵²

Tingle and Gorsline¹⁵³ were able to prepare Grignard reagents in ligroïn (b. 36°) by the addition of relatively small amounts of ethyl ether, quinoline or pyridine. In one experiment they combined 7.8 g. of ethyl

¹⁴⁸ Malmgren, *Ber.*, 36, 2608-42 (1903).

¹⁴⁹ Tschelinzeff, *Ber.*, 37, 4534-40 (1904).

¹⁵⁰ Tschelinzeff, *Ber.*, 38, 3664-73 (1905).

¹⁵¹ Stadnikoff, *Ber.*, 44, 1157-60 (1911); *J. prakt. Chem.*, [2], 88, 1-20 (1913); Stadnikoff and Kusmina-Aron, *ibid.*, [2], 88, 20-5 (1913).

¹⁵² Hess and Rheinboldt, *Ber.*, 54B, 2043-55 (1921).

¹⁵³ Tingle and Gorsline, *Am. Chem. J.*, 37, 483-94 (1907).

iodide, 1.22 g. of magnesium, 500 ml. of ligroin and 30 ml. of quinoline. There was no evident reaction at room temperature, but the magnesium disappeared upon twenty minutes boiling.

It may be noted, parenthetically, that at higher temperatures, quinoline apparently reacts with Grignard reagents. Thus, when Oddo¹⁵⁴ heated an iodine-activated mixture of 6 g. of magnesium, 40 g. of bromobenzene, 50 ml. of toluene and 32 g. of quinoline in an oil bath at 140°, and then hydrolyzed the reaction mixture, he was able to isolate α -phenylquinoline from the hydrolysis product.

Pickard and Kenyon¹⁵⁵ boiled a mixture of 250 ml. of dry, thiophene-free benzene, 1.5 g. of methyl iodide, and 0.3 g. of magnesium powder for several hours without being able to detect any reaction. They then added 3.0 g. of tribenzylphosphine oxide. After a short time the clear liquid became cloudy, and magnesium began to dissolve. After seven hours reflux the solution was filtered hot. On cooling, small, colorless prismatic needles separated. The analysis was consistent with the formulation $2(C_6H_5CH_2)_3PO \cdot CH_3MgI$.

A comparative study of the effectiveness of various ethers and their sulfur analogs in facilitating Grignard reagent formation in benzene solution has been made by Hepworth.¹⁵⁶ The method used consisted in introducing 1 g. of the substance to be investigated, 0.3 g. of magnesium and 2 g. of methyl iodide into 50 ml. of dry benzene, and submitting the mixture to reflux on a water-bath. The following conclusions were drawn. In general, oxygen compounds are much more effective than their sulfur analogs. Open-chain compounds are more effective than the related heterocycles: e.g., ethyl *n*-propyl ether is more effective than pentamethylene oxide; ethyl *n*-propyl sulfide is more effective than pentamethylene sulfide. 1,4-Dithiane and 1,4-dioxane are more active than pentamethylene sulfide and oxide, respectively, but much less active than the corresponding open-chain sulfide and ether respectively. 1,4-Thioxane is more effective than 1,4-dithiane, being almost the equal of 1,4-dioxane. Ethyl selenide and methyl telluride are about equal to ethyl sulfide. Phenyl sulfoxide and isoamyl sulfoxide are effective, and form Grignard reagent complexes. Methyl sulfone and phenyl sulfone are ineffective. The rate of reaction does not depend upon the basicity of the "catalyst."

Gilman and McCracken¹⁵⁷ have reviewed earlier work on the preparation of Grignard reagents in solvents other than ethyl ether, and have investigated the effect on Grignard reagent yields of various hydrocarbon-ethyl ether mixtures. They conclude that, in general, the use of a mixed solvent results in a drop in yield of about 10 percent below that obtained

¹⁵⁴Oddo, *Atti acad. Lincei*, [5], 16, 1, 538-45 (1907); *Chem. Zentr.*, 1907, II, 73.

¹⁵⁵Pickard and Kenyon, *J. Chem. Soc.*, 89, 262-73 (1906).

¹⁵⁶Hepworth, *J. Chem. Soc.*, 119, 1249-56 (1921).

¹⁵⁷Gilman and McCracken, *Rec. trav. chim.*, 46, 463-72 (1927).

with the optimum ethyl ether concentration. They recommend that, when the use of a mixed solvent is desirable in subsequent reaction, the Grignard reagent be prepared in a minimal quantity of ethyl ether and that the hydrocarbon then be added.

The preparation of alkylmagnesium halides in benzene, without the aid of activators or "catalysts," has been studied by Schlenk.¹⁵⁸ One-tenth mole of alkyl halide, 5 g. of sandpapered magnesium ribbon and 100 ml. of benzene were sealed in a glass tube and mechanically shaken for two months. The yield of Grignard reagent was estimated by acid titration, and the amount of Wurtz product was calculated with the aid of a supplementary halide-ion determination. Results are recorded in Table II-XI.

TABLE II-XI

REACTION OF MAGNESIUM WITH ALKYL HALIDES IN BENZENE

Halide	Yield RMgX (%)	Yield Wurtz Product (%)
CH ₃ I	0	...
C ₂ H ₅ I	11.2	10.8
n-C ₃ H ₇ I	1.0	4.0
n-C ₄ H ₉ I	96.0	4.0
n-C ₇ H ₁₅ I	3.0	3.0
n-C ₈ H ₁₇ I	96.0	4.0
C ₂ H ₅ Br	2.0	5.0
n-C ₄ H ₉ Br	38.0	...
n-C ₄ H ₉ Cl	55.0	...

Schlenk also investigated a considerable number of iodine-activated Barbier-type reactions of esters and ketones in benzene.

Unable to prepare 2,4,6-triphenylphenylmagnesium bromide in ethyl ether (possibly because of its low solubility in that medium), Kohler and Blanchard¹⁵⁹ had resort to the following procedure. "To a solution of 20 g. of the bromo compound in 22 g. of boiling xylene were added 5 g. of magnesium, 4 ml. of a dilute ethereal ethylmagnesium bromide solution and 10 drops of ethyl bromide. The mixture was boiled and stirred vigorously until the reaction started. More bromo compound was then added at fifteen-minute intervals, along with benzene and ether, until 70 g. of the bromo compound, 150 ml. of benzene, and 50 ml. of ether had been added. After continued boiling for two and one-half hours, most of the magnesium had dissolved." Subsequent carbonation of the Grignard reagent so prepared yielded 53.5 g. (84.1 percent) of 2,4,6-triphenylbenzoic acid.

Barré and Repentigny¹⁶⁰ describe the preparation of several Grignard reagents in hydrocarbon solvents with dimethylaniline as "catalyst."

¹⁵⁸ Schlenk, *Ber.*, 64B, 739-43 (1931).

¹⁵⁹ Kohler and Blanchard, *J. Am. Chem. Soc.*, 57, 367-71 (1935).

¹⁶⁰ Barré and Repentigny, *Can. J. Research*, 27B, 716-20 (1949).

(Diethyl-, di-*n*-propyl-, and di-*n*-butylaniline are said to perform less satisfactorily.) Their data are summarized in Table II-XII; yields were determined by acid titration (see Chapter III, Estimation and Detection of Grignard Reagents).

TABLE II-XII

PREPARATIONS OF SEVERAL GRIGNARD REAGENTS IN HYDROCARBON SOLVENTS WITH THE AID OF DIMETHYLANILINE

Halide	Solvent	Grams Amine	Hours Reflux	Temp. (°C)	Yield (%)
C ₂ H ₅ I	C ₆ H ₆	0.05	5-7	80	82
C ₂ H ₅ I	CH ₃ C ₆ H ₅	0.05	5-7	80	82
C ₂ H ₅ Br	C ₆ H ₆	0.33	4-7	80	96
C ₂ H ₅ Br	Ligroin*	1.00	4-7	90-100	94
<i>n</i> -C ₄ H ₉ Cl	C ₆ H ₆	1.25	11-18	80	90-96
<i>n</i> -C ₄ H ₉ Cl	Ligroin*	1.25	11-18	90-100	92
<i>s</i> -C ₄ H ₉ Cl	C ₆ H ₆	1.25	14	80	86
<i>i</i> -C ₅ H ₁₁ Cl	C ₆ H ₆	1.25	14	80	80
C ₆ H ₅ Br	C ₆ H ₆	1.25	14	80	81
C ₆ H ₅ CH ₂ Cl †	C ₆ H ₆	1.25	14	80	20-30

* B.p., 80-100°.

† Benzyl chloride quaternizes to some extent; neither allyl bromide nor *t*-butyl chloride give appreciable yields of Grignard reagent.

Kuznetsov¹⁶¹ has prepared *n*-propyl-, isobutyl-, and isoamylmagnesium iodides in xylene with the aid of a few drops of dimethylaniline.

According to Neogi,¹⁶² Grignard reagents may be prepared in "neutral solvents" with the aid of "catalytic quantities" of triethylsulfonium iodide [(C₂H₅)₃SiI]. Methyl, ethyl, *n*-propyl, isobutyl, and isoamyl iodides are mentioned as yielding Grignard reagents by this method.

Oddo¹⁶³ has reported several Barbier-type syntheses with alkyl iodides, benzene, magnesium, and aldehydes.

Schorigin *et al.*¹⁶⁴ describe unsuccessful attempts to prepare *n*-butyl- and isoamylmagnesium chlorides in toluene with iodine-activated magnesium.

PREPARATION OF GRIGNARD REAGENTS WITHOUT SOLVENT (OTHER THAN EXCESS HALIDE)

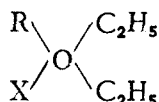
Contrary to the opinion of some early investigators, who held that the formation of an ether-halide complex of the type

¹⁶¹ Kuznetsov, *J. Gen. Chem.* (U.S.S.R.), 12, 631-7 (1942); *Chem. Abstr.*, 38, 1494 (1944).

¹⁶² Neogi, *Proc. Asiatic Soc. Bengal, Proc. 8th Indian Sci. Cong.*, 17, cxxxii (1921); *Chem. Abstr.*, 17, 3478 (1923).

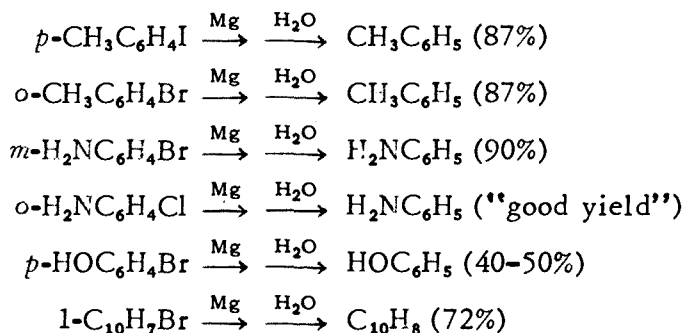
¹⁶³ Oddo, *Gazz. chim. ital.*, 41, 1, 273-94 (1911); *Chem. Abstr.*, 5, 2639 (1911).

¹⁶⁴ Schorigin, Issagulianz, and Gussewa, *Ber.*, 66B, 1426-31 (1933).



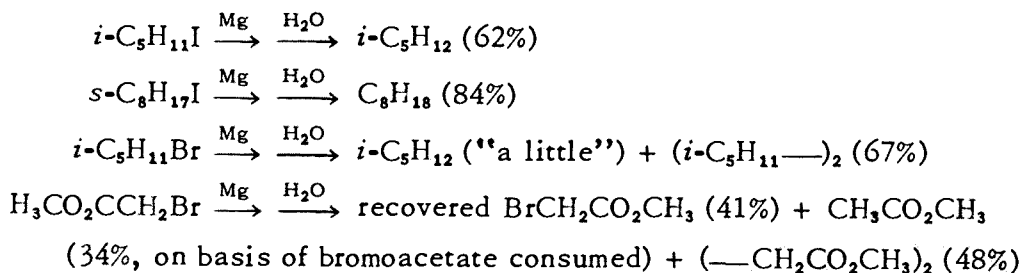
was a necessary prerequisite to reaction with magnesium to form a Grignard reagent, it was shown by Spencer and Stokes¹⁶⁵ that many Grignard reagents may be prepared merely by heating the halide with magnesium. There is always an appreciable proportion of Wurtz product, and usually, when disproportionation is possible, of disproportionation products as well.

Spencer and Stokes found that iodobenzene gave a product which, upon hydrolysis yielded 44 percent of benzene and 54 percent of biphenyl. Bromobenzene behaved similarly, although it reacted less readily with magnesium. Other similar reactions carried out by Spencer and Stokes were:



Bromoacenaphthene and bromosuccinic acid also reacted in this way, but the method did not appear to be applicable to benzylidene chloride, *p*-chlorophenol, *o*-chlorophenol, 1-chloronaphthalene, *p*-chlorotoluene, methyl iodide, methylene iodide, trimethylene iodide or isopropyl iodide.

The study described was extended by Spencer and Crewdson:¹⁶⁶



Chlorobenzene heated in a sealed tube with magnesium for six hours at 270°, then cooled and treated with water yielded 60 percent of benzene. Methyl iodide, ethyl bromide, ethyl chloride and isobutyl chloride, heated with magnesium in sealed tubes at *ca.* 250° for six to eight hours yielded

¹⁶⁵ Spencer and Stokes, *J. Chem. Soc.*, 93, 68-72 (1908).

¹⁶⁶ Spencer and Crewdson, *J. Chem. Soc.*, 93, 1821-6 (1908).

some Grignard reagent, together with varying quantities of Wurtz products, unsaturated gases, and hydrogen.

Gilman and Brown¹⁶⁷ report that when 11.2 g. (0.1 mole) of chlorobenzene and 3.6 g. (0.15 g.-atom) of magnesium were sealed in an evacuated bomb-tube and heated at 150–160° for three hours, and the light-brown, powdery product was washed with benzene and dissolved in 1:1 ether-benzene solution and titrated, the result indicated an 84 percent yield of Grignard reagent. (There was no reaction at 140°; at temperatures higher than that employed there was charring.)

Shorigin *et al.*¹⁶⁸ prepared the Grignard reagent from chlorobenzene without the aid of solvents. They used an iron autoclave, equipped with a mechanical stirrer, operated under 2.5 atmospheres pressure for three to three and one-half hours at 160–165°. The best yield of Grignard reagent (calculated as C_6H_5MgCl), evaluated by dilute sulfuric acid titration, was 70 percent on the basis of the chlorobenzene consumed (59 percent on the basis of the magnesium consumed), obtained when the reactants were combined in the ratio of 4 moles of chlorobenzene per gram-atom of magnesium. The byproducts were biphenyl and a little terphenyl. The amount of biphenyl formed depended on the relative proportions of the reactants: 1.5 Mg + 1 C_6H_5Cl , 8 percent; 1.2 Mg + 1 C_6H_5Cl , 14 percent; 1.0 Mg + 1 C_6H_5Cl , 16 percent.

Unsuccessful attempts to prepare *n*-butyl-, isoamyl-, and *n*-octylmagnesium chlorides by refluxing magnesium in the respective alkyl chlorides are also reported.¹⁶⁹

According to Weissenborn,¹⁷⁰ phenylmagnesium chloride or its homologs may be prepared by boiling chlorobenzene or its homologs with magnesium or an alloy of magnesium in the presence of an activator, such as cuprous chloride, aluminum bromide, or iodine. In an amendment to the original patent, Weissenborn¹⁷¹ claims that the activator may be omitted if the magnesium is thoroughly clean.

Andrianov and Gribanova¹⁷² advocate the use of ethyl orthosilicate $(C_2H_5O)_4Si$ as an activator or "catalyst." According to them, alkyl or aryl halides react with magnesium in the presence of a little ester to give

¹⁶⁷ Gilman and Brown, *J. Am. Chem. Soc.*, 52, 3330–2 (1930).

¹⁶⁸ (a) Shorigin, Issaguljan, Gussewa, Ossipowa, and Poljakowa, *Ber.*, 64B, 2584–90 (1931); (b) Shorigin and Issaguljan, *Trans. VI Mendeleev Congr. Theoret. Applied Chem.* 1932, 2, Pt. 1, 973–80 (1935); *Chem. Zentr.*, 1936, II, 2345; *Chem. Abstr.*, 30, 4157 (1936).

¹⁶⁹ Schorigin, Issaguljan, and Gussewa, *Ber.*, 66B, 1426–31 (1933).

¹⁷⁰ Weissenborn, German Patent 660,075, May 17, 1938; *Chem. Abstr.*, 32, P5857 (1938).

¹⁷¹ Weissenborn, German Patent, 697,420, Sept. 19, 1940; *Chem. Abstr.*, 35, P6600 (1941).

¹⁷² Andrianov and Gribanova, *J. Gen. Chem. (U.S.S.R.)*, 8, 552–6 (1938); *Chem. Abstr.*, 32, 7892 (1938).

"good" yields of the corresponding Grignard reagents. The exothermic reaction proceeds in the absence of ether and is completed without external heating, or by digesting at 40–50° for an hour and a half.

It is said that equally good results are obtained when to 12 g. of magnesium and a few drops of ethyl orthosilicate, one-half of the halide is introduced dropwise directly, and the other half dissolved in 4–5 parts of toluene or xylene. In this way, the following Grignard reagents were prepared in the indicated percentage yields: C_2H_5MgBr , 96; $i-C_4H_9MgCl$, 51; $i-C_5H_{11}MgBr$, 58.5; $n-C_6H_{13}MgBr$, 60; $n-C_8H_{17}MgBr$, 35; C_6H_5MgBr , 23–25.

Manske and Ledingham¹⁷³ have prepared phenylmagnesium chloride by refluxing magnesium in an excess of chlorobenzene, with the aid of iodine activation when necessary. About ten hours is required for complete dissolution of 72 g. (3.0 g.-atoms) of magnesium in 1000 g. (8.9 moles) of chlorobenzene. When a batch of Grignard reagent so prepared was treated with 99 g. (2.25 moles) of ethylene oxide the yield of phenethyl alcohol obtained was 185 g. (ca. 1.5 mole)—about 50.5 percent on the basis of magnesium expended, or 67.4 percent on the basis of ethylene oxide used. Of especial interest is their report that small amounts of 4-biphenylethanol and 4-terphenyl-4-ethanol were also isolated.

Similarly prepared phenylmagnesium chloride, when carbonated, yielded benzoic, 4-biphenylcarboxylic, and 4-terphenyl-4-carboxylic acids.

As might be expected, biphenyl and terphenyl were present in both cases.

MECHANISM AND KINETICS OF GRIGNARD REAGENT FORMATION

The earlier contributions to this subject were purely speculative and may now be either disregarded as contrary to known facts or reinterpreted in the light of fuller knowledge. Although comparatively few studies have been directed primarily toward the solution of the problems involved, the accumulation of incidental evidence permits the presentation of a credible, though somewhat incomplete description of the process of organomagnesium halide formation.

Mindful of the facts that most organic halides appear remarkably unreactive toward magnesium in inert media such as benzene, and that reaction in such media may often be "catalyzed" by the addition of relatively small quantities of ether or tertiary amines, Tschelinzeff¹⁷⁴ advanced the hypothesis that the actual reactant with magnesium is an oxonium or quaternary ammonium salt. To this proposal, Grignard¹⁷⁵ offered the objection that, as compared to alkyl halides, quaternary ammonium halides are conspicuously inert toward magnesium. Meisenheimer

¹⁷³ Manske and Ledingham, *Can. J. Research*, 27, 158–60 (1949).

¹⁷⁴ Tschelinzeff, *Ber.*, 37, 4534–40 (1904).

¹⁷⁵ Grignard, *Bull. soc. chim.*, [4], 1, 256–62 (1907).

and Casper¹⁷⁶ pointed out, further, that, although the formation of phenylmagnesium iodide in inert solvents is "catalyzed" by tertiary amines, iodobenzene does not form quaternary ammonium salts. They also added the further objection that the interaction of magnesium with an organic halide in the presence of an ether or a tertiary amine yields only the Grignard reagent corresponding to the original organic halide—never a mixture of Grignard reagents, as might reasonably be expected if the true organic reactant were an oxonium or quaternary ammonium salt. To this, if further argument be necessary, may be added the now known facts that ethereal solutions of organic halides in general, display none of the characteristic properties of oxonium salt solutions, and that some Grignard reagents, at least, may be prepared, though with relative difficulty, in inert solvents or without benefit of solvent other than excess halide.

In the light of present knowledge the most plausible hypothesis concerning the function of such agents as ethers and tertiary amines in Grignard reagent formation is that they are not catalysts in the generally accepted sense of the term. They merely make possible the continuation of a reaction they have had no part in initiating by facilitating removal of the product of reaction from the surface of the magnesium, which would otherwise be occluded and inactivated.

In a preliminary study on the kinetics of Grignard reagent formation, Kilpatrick and Simons¹⁷⁷ concluded that reaction between ethereal ethyl bromide and magnesium is initiated only at points of contact (magnesium-glass or magnesium-magnesium). The use of iodine as an "activator" reduces the induction period, but does not alter the rate of reaction otherwise. After the induction period, the rate of reaction is proportional to the ethyl bromide concentration and to the magnesium surface exposed.

In an extension of this study, Gzinski and Kilpatrick¹⁷⁸ made use of an improved modification of the apparatus originally employed. A freshly polished, or etched, magnesium cylinder served as the source of metal. Vertically aligned, it was rotated at high speed in contact with two vertically aligned shoes which were adjusted so that no actual abrasion of the magnesium took place. Under constant temperature control ($25 \pm 0.05^\circ$) reproducible rates were thus obtained. The nature of the contact material did not greatly affect the rate of reaction as measured by the rate of dissolution of magnesium, but did in some cases affect the yield of Grignard reagent. (Copper and aluminum shoes both gave lower yields than glass shoes.) Gzinski and Kilpatrick conclude that the essential function of the contact is to facilitate the rupture of any coating originally present on the magnesium and then to prevent contamination of the surface with products. They found that, when the magnesium surface remains

¹⁷⁶ Meisenheimer and Casper, *Ber.*, 54B, 1655-65 (1921).

¹⁷⁷ Kilpatrick and Simons, *J. Org. Chem.*, 2, 459-69 (1938).

¹⁷⁸ Gzinski and Kilpatrick, *J. Org. Chem.*, 5, 264-75 (1940).

constant in extent, increased halide concentration increases the rate of reaction as measured by the rate of metal dissolution, but decreases the ratio of active Grignard reagent to magnesium halide in the reaction product. This observation is in accord with those of Gilman *et al.*¹⁷⁹ on the effects of ether dilution and rate of halide addition on Grignard reagent yields.

Their observation on the effect of iodine is also consistent with the conclusion that can be drawn from earlier work on "activators" (see Activators and Inhibitors, p. 8). In general, "activators" facilitate the preparation of Grignard reagents by materially shortening the induction period. It appears to be a reasonable hypothesis that they do so either by cleansing the magnesium surface or by introducing free radicals (through the agency of magnesiumous halides) or by a combination of both effects.

Kondyrew¹⁸⁰ first observed that when externally connected platinum and magnesium electrodes are immersed in an ethereal ethyl bromide solution, magnesium dissolves and a potential is set up. Brun,¹⁸¹ who studied this effect in more detail, found the potential so produced to be characteristic of the individual halide and of its concentration. What is much more pertinent to the present discussion, however, he measured the actual passage of current between the electrodes and found it to be extremely small. For example, during the dissolution of 2.25 g. of magnesium in an ethyl bromide solution, less than 0.1 coulomb of current passed, as compared with the 18,093 coulombs calculable for the dissolution of a like amount of metal in an ordinary electrical cell. The conclusion that Grignard reagent formation is essentially a non-ionic reaction appears inescapable.

The suggestion made by Gomberg and Bachmann¹⁸² to account for iodine or magnesium iodide activation of magnesium, and subsequently adopted by Gilman *et al.*,¹⁸³ namely, that organomagnesium halide formation is a radical reaction in which magnesiumous halides participate is consistent with the known facts. Gomberg and Bachmann believe, as did Grignard,¹⁸⁴ that when no activator is present, reaction is initiated through the agency of small amounts of magnesium halide arising from the Wurtz reaction. This, of course, begs the question of the nature of the Wurtz reaction and its relationship to the Grignard reaction. If this view be accepted, their scheme should be amended to include the corresponding disproportionation reactions:

¹⁷⁹(a) Gilman and McCracken, *Rec. trav. chim.*, 46, 463-72 (1927); (b) Gilman, Zoellner, and Dickey, *J. Am. Chem. Soc.*, 51, 1576-83, 1583-7 (1929).

¹⁸⁰Kondyrew, *Ber.*, 58B, 459-63 (1925).

¹⁸¹Brun, *J. chim. phys.*, 36, 147-59 (1939).

¹⁸²Gomberg and Bachmann, *J. Am. Chem. Soc.*, 49, 236-57 (1927).

¹⁸³(a) Gilman and Fothergill, *J. Am. Chem. Soc.*, 50, 3334-41 (1928); (b) Gilman and Kirby, *ibid.*, 51, 1571-6 (1929).

¹⁸⁴Grignard, *Bull. soc. chim.*, [4], 1, 256-62 (1907).

- (1a) $2 \text{RX} + \text{Mg} \longrightarrow \text{MgX}_2 + \text{R}_2$
 (1b) $2 \text{RX} + \text{Mg} \longrightarrow \text{MgX}_2 + \text{R}_{(+\text{H})} + \text{R}_{(-\text{H})}$
 (2) $\text{MgX}_2 + \text{Mg} \rightleftharpoons 2 \cdot \text{MgX}$
 (3) $\text{RX} + \cdot \text{MgX} \longrightarrow \text{MgX}_2 + \text{R}\cdot$
 (4) $\text{R}\cdot + \cdot \text{MgX} \longrightarrow \text{RMgX}$

There would appear to be no compelling reason to regard these radicals as "free" in the sense that they occur in significant numbers in the body of the solution. The processes described might very well take place at the solid-liquid interface.

Most of the commonly encountered by-products of the preparation of Grignard reagents can also be accounted for on the basis of radicals, and it is notable that they are in general the same as those produced by the electrolytic discharge of Grignard anions. These are the so-called Wurtz products, the disproportionation products, and the products that may be attributed to the attack of free radicals upon the solvent.

The mechanism of the sodium Wurtz-Fittig reaction has been the subject of extensive study and discussion,¹⁸⁵ and convincing arguments can be made out for a free-radical process on the one hand or an interaction between arylsodium and an organic halide on the other. Probably both processes take place, depending upon the reactants and the experimental conditions.

With metallic magnesium, which has a higher discharge potential than sodium, the free-radical mechanism might well be expected to predominate. As a matter of fact, it is well known that appreciable quantities of biphenyl are always produced in the preparation of phenylmagnesium halides, whereas the reaction



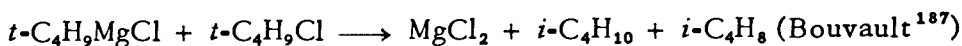
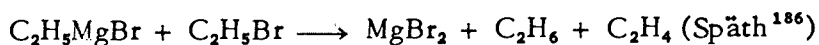
does not take place. Indeed, the allyl halides are among the relatively few conspicuous exceptions to the rule that, under the conditions ordinarily employed in the preparation of Grignard reagents, organic halides do not react with their own Grignard reagents.

The disproportionation reactions which take place at the surface of the metal are closely akin to the Wurtz reaction and probably go through a free-radical mechanism also. The more reactive free radicals like methyl (and undoubtedly the aryl radicals) attack the solvent to some extent and couple to some extent. The less reactive free radicals, such as the benzyl, which cannot disproportionate, couple or attack the solvent. Radicals, such as the ethyl and the *t*-butyl disproportionate almost completely with traces only of coupling products, if any. For the alkyl radicals that are not too highly branched, the tendency toward coupling in-

¹⁸⁵ Cf., e.g., Bachmann and Clark, *J. Am. Chem. Soc.*, 49, 2089-98 (1927).

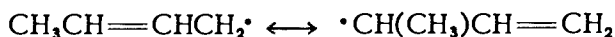
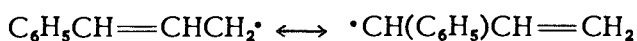
creases and the tendency toward disproportionation decreases with increasing molecular weight.

Disproportionation may also take place in solution by interaction between the halide and its Grignard reagent, but this reaction usually requires higher temperatures than does the formation of the Grignard reagent.

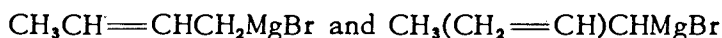


Studies of the gaseous byproducts evolved in the preparation of alkylmagnesium halides have been made by Tschelinzeff,¹⁸⁸ by Jolibois,¹⁸⁹ by Job *et al.*,¹⁹⁰ and by Gilman and Fothergill (*loc. cit.*^{183a}).

Granting that the electrical effects previously discussed exclude an ionic reaction mechanism for Grignard reagent formation, further evidence of a radical mechanism is to be seen in the structural peculiarities of the Grignard reagents prepared from such allylic halides as cinnamyl chloride¹⁹¹ and crotyl- and α -methallyl bromides.¹⁹² The corresponding free radicals are resonant structures which may be described by the canonical forms:



The Grignard reagent from cinnamyl chloride reacts chiefly as though it had the structure $\text{CH}_2=\text{CH}(\text{C}_6\text{H}_5)\text{CHMgCl}$; that from crotyl bromide, from α -methallyl bromide, or from mixtures thereof in various proportions, as though it were a mixture of



These phenomena are discussed in more detail in Chapter XVII, Allylic Rearrangements in Grignard Reactions.

It may also be noted that optically active halides of the types $\text{RR}'\text{C}^*\text{HX}$ and $\text{RR}'\text{R}''\text{C}^*\text{X}$ react with magnesium to give optically inactive Grignard reagents, which in turn react with co-reactants to give optically inactive products.¹⁹³

¹⁸⁶ Späth, *Monatsh.*, 34, 1965-2014 (1913).

¹⁸⁷ Bouvault, *Compt. rend.*, 138, 1108-10 (1904); *J. Chem. Soc.*, 86, I, 546 (1904). See also: Madelung and Volker, *J. prakt. Chem.*, [2], 115, 24-44 (1927); Gilman and Zoellner, *J. Am. Chem. Soc.*, 50, 425-8 (1928).

¹⁸⁸ Tschelinzeff, *J. Russ. Phys.-Chem. Soc.*, 36, 549-54 (1904); *J. Chem. Soc.*, 86, I, 641 (1904).

¹⁸⁹ Jolibois, *Compt. rend.*, 155, 213-5 (1912); *Chem. Abstr.*, 6, 2740 (1912).

¹⁹⁰ Job, Reich, and Dubien, *Bull. soc. chim.*, [4], 37, 976-7 (1925).

¹⁹¹ Gilman and Harris, *J. Am. Chem. Soc.*, 53, 3541-6 (1931).

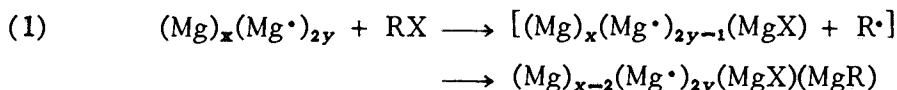
¹⁹² Young, Winstein, and Prater, *J. Am. Chem. Soc.*, 58, 289-91 (1936).

¹⁹³ See, e.g.: Porter, *J. Am. Chem. Soc.*, 57, 1436 (1935).

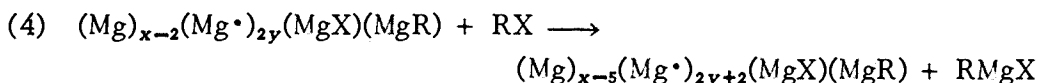
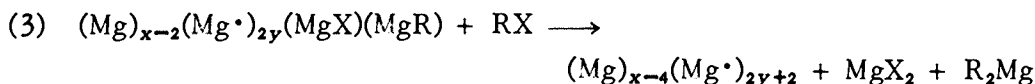
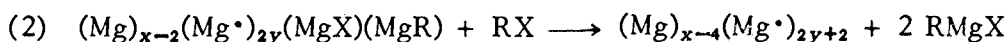
A proposed reaction scheme. In order to take as full account as possible of the qualitative and quantitative observations herewith reviewed, and at the same time to provide a basis for elucidation of the various side-reactions that occur during Grignard reagent formation, the authors propose a modification of the reaction scheme of Gomberg and Bachmann (*loc. cit.*¹⁸²). Although admittedly speculative, the concept offered appears to constitute a useful working hypothesis in that it is consistent with all the well-established facts and that it affords a basis of correlation for a considerable mass of empirical data.

It seems probable that a clean, fresh, mechanically-created surface of metallic magnesium includes many points of unsaturation* which may be regarded as centers of exceptional reactivity. Even brief exposure to ordinary atmospheres undoubtedly destroys many such centers by chemical action; probably others disappear upon aging in inert atmospheres by a process akin to annealing. These ideas would seem to account sufficiently for the extraordinary efficacy of the method of "mechanical activation" previously discussed.

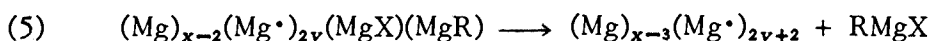
It is, perhaps, wiser to avoid diagrammatic representations as tending to suggest physical pictures that may be subject to too-literal interpretation. For purposes of entering into illustrative detail, however, a particle of metallic magnesium with its points of surface unsaturation may be represented by the symbol $(Mg)_x(Mg\cdot)_{2y}$, in which, of course, $x \gg 2y$. The initial reaction of a clean, partially unsaturated surface of magnesium with an organic halide may be represented by equation 1.



Subsequent reaction steps that might lead to Grignard reagent formation may be represented by equations 2, 3, and 4.

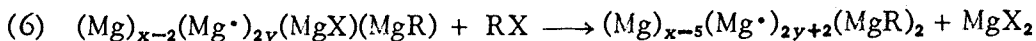


Possibly adjacent MgX and MgR groups may react in the sense of equation 5.



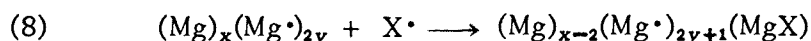
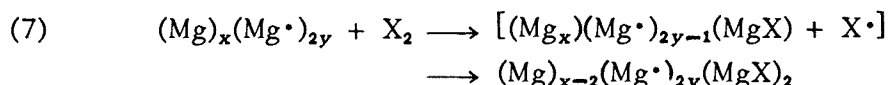
* For the sake of simplicity, points of unsaturation are represented in the equations that follow as actual free valences. No doubt lattice distortions resulting in elongated or otherwise strained intermetallic bonds also constitute centers of exceptional reactivity, at least in so far as the more reactive halides are concerned.

Another reaction not leading directly to Grignard reagent formation, but which might ultimately do so, or which might, on the other hand, lead to Wurtz product formation is suggested in equation 6.

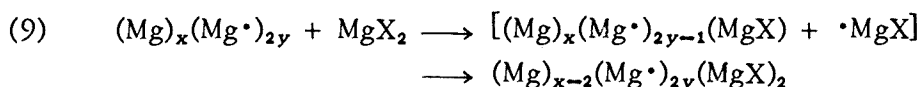


The tendency for the reactivity of the surface* to increase as reaction progresses is probably exaggerated in equations 2-5 as written, for it seems likely that at least some adjacent centers of unsaturation would undergo mutual saturation before being subjected to further halide attack. However, a net effect in the qualitative sense indicated would explain in part at least: (a) the inductive period observed at the beginning of the halide-magnesium reaction; (b) the tendency of the reaction rate to increase as reaction proceeds; (c) the efficacy of relatively reactive halides (*e.g.*, ethyl bromide) as magnesium activators; and (d) in part, at least, the efficacy of the "entrainment" method of preparation.

The process of halogen activation probably involves both the attack of molecular halogen upon preëxistent reactive centers (equation 7) and the attack of atomic halogen upon the saturated metallic surface (equation 8).



Magnesium halide activation is probably initiated at points of unsaturation only (equation 9).



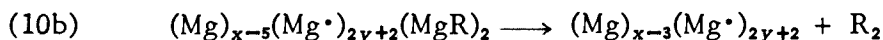
The commonly accepted idea that a small amount of preformed Grignard reagent solution serves as an activator may have no basis beyond the fact that such a solution would contain a certain amount of magnesium halide, partly as a consequence of Wurtz or disproportionation side-reactions occurring during its formation, and partly as a consequence of the Schlenk equilibrium (see Chapter IV, Constitution and Dissociation of the Grignard Reagent). However, it would be quite possible to write an equation analogous to equation 9 in which MgX_2 is replaced by RMgX or R_2Mg .

*Centers of exceptional reactivity (or, more briefly, reactive centers) may be taken to include actual points of unsaturation (Mg^\bullet) and surface-adherent halogen atoms (MgX) and organic radicals (MgR). Reactivity (toward organic halides) is presumed to decrease in the order: $(\text{Mg}^\bullet) > (\text{MgX}) > (\text{MgR}) \gg (\text{Mg})_x$. Surface reactivity may increase either through an increase in the number of reactive centers (equation 4) or an increase in the reactivity of a constant number of reactive centers (equations 2 and 3).

The Wurtz and disproportionation reactions. Concerning the Wurtz reaction, present knowledge of the behavior of free radicals in solution enables us to discount certain proposed mechanisms as either improbable or incapable of general application. In the cases of such highly reactive free radicals as the phenyl, or even the methyl, the notion that they could survive long enough in the presence of any of the usual Grignard solvents to undergo the reaction

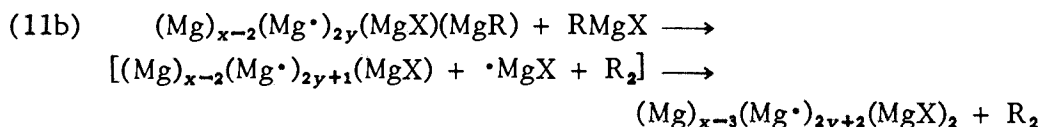
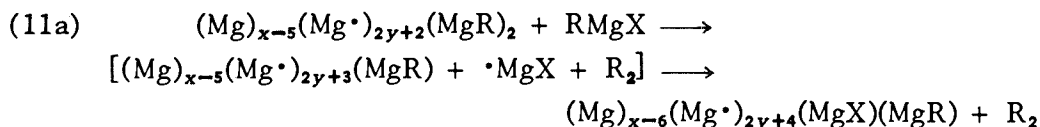


to an appreciable extent is absurd. Surface-attached radicals, however, probably have a considerable degree of surface mobility (through simultaneous bond scission and bond formation) and it seems altogether probable that two adjacent radicals might form a dimer through a reaction which might be represented as in equations 10a, b.



The net energy change would certainly favor such reactions. An increase in the temperature of the reaction system might be expected both to increase the surface mobility of radicals and to contribute to any energy of activation that might be required for the dimerization—an effect consistent with the empirical observation that, in general, higher reaction temperatures favor Wurtz product formation.

Another probable source of Wurtz product that should not be ignored may be represented as in equations 11a, b.

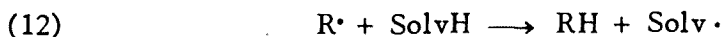


The disproportionation reactions are very closely allied to the Wurtz reaction, and whether one or the other occurs is determined principally by the nature of the radical involved. For alkyl radicals (other than methyl) equations 10 and 11 may be rewritten with the substitution of $R_{(+H)} + R_{(-H)}$ for R_2 .

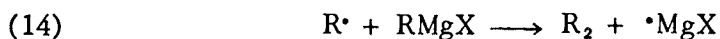
Reactions involving the solvent. Whether or not free radicals ever actually escape into the body of the solution in significant quantities is a question that can scarcely be answered with any assurance. However, it is altogether conceivable that under favorable experimental conditions

they do, in which case it may be said that their ultimate fate depends on both the nature of the free radical concerned and the nature of the solvent medium.

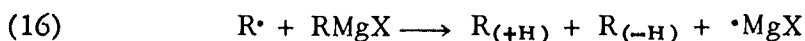
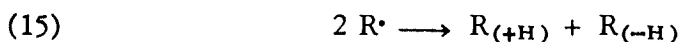
Solvents containing relatively labile hydrogen atoms are attacked by the more reactive (*i.e.*, in general, the more "electronegative"¹⁹⁴) radicals, including, *e.g.*, methyl and phenyl.



In such solvents the less reactive radicals (*i.e.*, those incapable of abstracting hydrogen atoms from the solvent) may be expected to accumulate in the system until their reactions with each other or with the Grignard reagent assume significant proportions. In the cases of radicals structurally incapable of disproportionation the Wurtz product is formed (equations 13 and 14).



In the cases of radicals structurally capable of disproportionation, that reaction may be expected to take place exclusively with alkyl radicals of low molecular weight, and predominantly with alkyl radicals of higher molecular weight (equations 15 and 16).



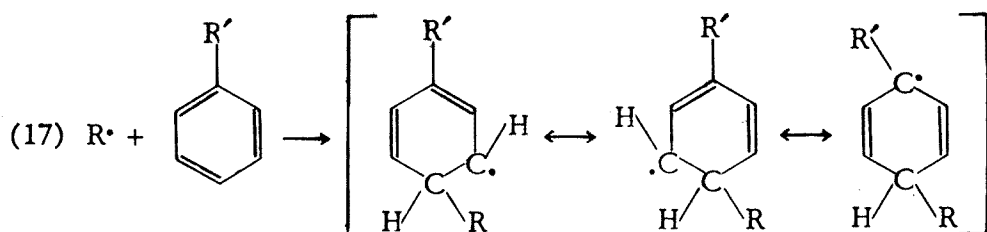
Aromatic solvents appear to react additively with radicals of all types. Thus, the reaction of benzyl chloride with magnesium in benzene produces (in addition to the Grignard reagent) both bibenzyl (the Wurtz product) and diphenylmethane; bromobenzene with magnesium in toluene produces both biphenyl and 4-methylbiphenyl.¹⁹⁵ When Manske and Ledingham¹⁹⁶ carbonated phenylmagnesium chloride solutions obtained by the reaction of magnesium with excess chlorobenzene, they were able to isolate (in addition to benzoic acid) small amounts of 4-biphenylcarboxylic and 4-terphenyl-4-carboxylic acids. Similarly, treatment of such solutions with ethylene oxide yielded (in addition to phenethyl alcohol) small amounts of 4-biphenylethanol and 4-terphenyl-4-ethanol.

Presumably the first step in such additive reactions must be a process like that described in equation 17.

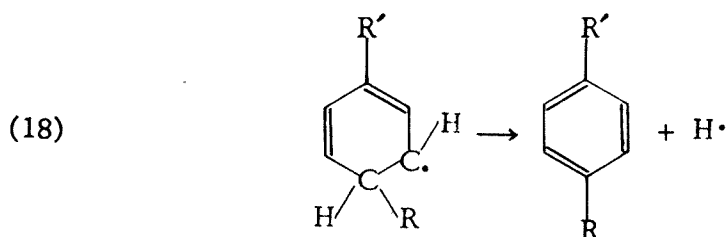
¹⁹⁴Concerning relative electronegativities of organic radicals, see: Kharasch and Reinmuth, *J. Chem. Education*, 5, 404-18 (1928); 8, 1703-48 (1931); Kharasch, Reinmuth, and Mayo, *ibid.*, 11, 82-96 (1934); 13, 7-19 (1936).

¹⁹⁵Kharasch, Goldberg, and Mayo, *J. Am. Chem. Soc.*, 60, 2004 (1938). Although water was added to the reaction systems described in this report, it has since been shown by Kane, Dissertation, University of Chicago, 1941, that the water does not enter into the reactions under discussion.

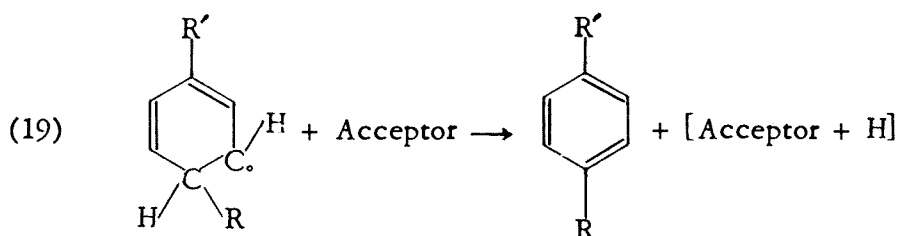
¹⁹⁶Manske and Ledingham, *Can. J. Research*, 27, 158-60 (1949).



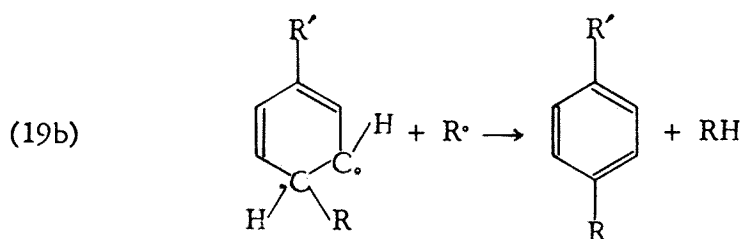
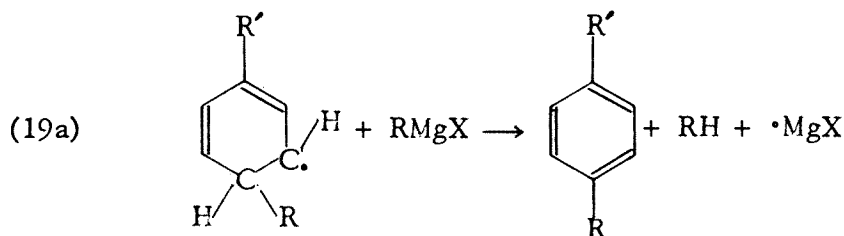
The fate of the excess (and undoubtedly extremely labile) hydrogen atom in the addition intermediate is as yet unknown. On the whole, a spontaneous dissociation of the type illustrated in equation 18 appears highly improbable.

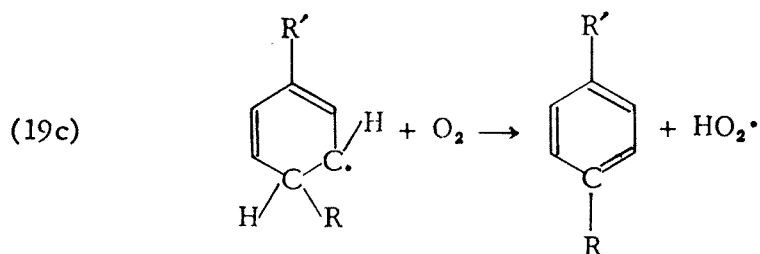


However, transfer to any available hydrogen acceptor should be effected very readily indeed (equation 19).

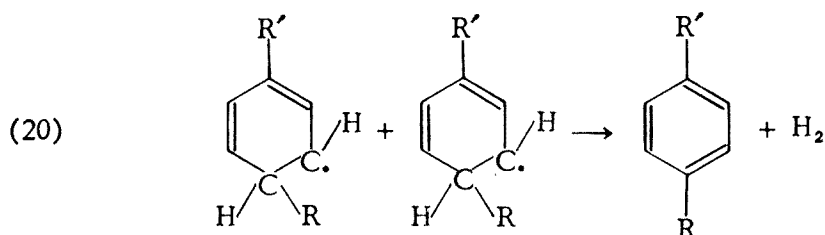


Credible transfers of this type are illustrated in equations 19a, b, c.





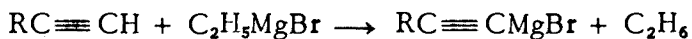
A disproportionation of the type suggested in equation 20 is not regarded as implausible *per se*, but as unlikely because of the high probability that reaction with some hydrogen acceptor would intervene to circumvent it.



The reactions just discussed (equations 12-20) have been represented as those of *free* radicals. It is possible, however, that some or all of these processes may involve surface-adherent radicals, at least in part. Whether by facilitating the detachment of adherent radicals to supply *free* radicals, or by increasing the reactivity of adherent radicals, an increase in temperature would favor any or all of the processes suggested.

HYDROGEN DISPLACEMENT METHODS OF GRIGNARD REAGENT PREPARATION

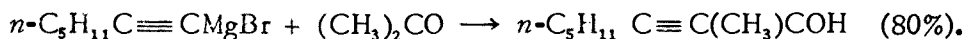
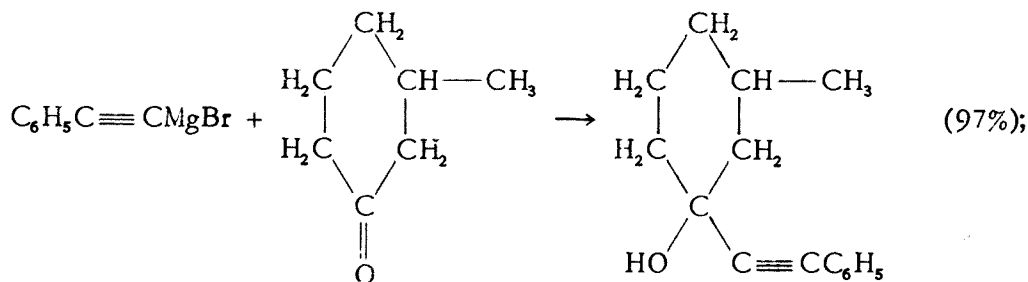
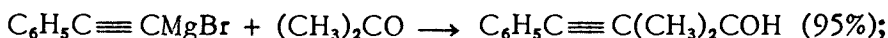
Acetylenic hydrocarbons.* Grignard reagents of the type $\text{RC}\equiv\text{CMgX}$ were first prepared by Iotsitch¹⁹⁷ by the method of hydrogen displacement.



Upon treatment of such acetylenic Grignard reagents with ketones and subsequent hydrolysis of the reaction mixtures, excellent yields of the expected tertiary alcohols were obtained:

* The preparations and reactions of acetylenic Grignard reagents have been reviewed by Piganiol, "Acetylene Homologs and Derivatives," English translation from the second revised French edition by Hessel and Rust, Mapleton House, Brooklyn, N. Y., 1950, Part 4, Chapter III, pp. 249-69. See also: Nieuwland and Vogt, "The Chemistry of Acetylene" Reinhold Publishing Corporation, New York, 1945 (Subject Index—Grignard reagents).

¹⁹⁷Iotsitch, J. Russ. Phys.-Chem. Soc., 34, 101-2 (1902); Bull. soc. chim., [3], 28, 922 (1902).



Iotsitch¹⁹⁸ obtained the expected products from phenylethynylmagnesium bromide and ethyl acetate, chloral, and 2,2,3-trichlorobutanal, respectively.

Meyer and Streuli¹⁹⁹ report that 1-octadecyne does not react with methylmagnesium bromide in boiling ethyl ether, but that reaction does take place in boiling *n*-butyl ether and can be followed quantitatively by measurement of the methane evolved. The resultant acetylenic Grignard reagent is said to be unreactive toward benzaldehyde, benzoyl chloride and methyl benzoate, but reacts normally with carbon dioxide (25 percent yield), the dinitrile of thapsic acid (85 percent yield), and with eicosane-3,18-dione (88 percent yield).

Kroeger and Nieuwland,²⁰⁰ however, apparently experienced no difficulty in preparing *n*-heptynyl-, *n*-hexyny-, or phenylethynylmagnesium halides from ethyl ethereal solutions of methylmagnesium iodide, ethylmagnesium bromide, or ethylmagnesium chloride. For the preparation of the bromides (from ethylmagnesium bromide) they describe their procedure as follows. "The calculated quantity of acetylenic hydrocarbon was dissolved in ether and added to the prepared Grignard [reagent], after which the solution was refluxed until no more ethane was evolved. In the case of quarter-mole runs, this required a half-hour for phenylacetylene and about two hours for alkylacetylenes."

According to them, the ethynylmagnesium chlorides are considerably less ether-soluble than the corresponding bromides or iodides or than ethylmagnesium chloride. When 0.5 mole of 1-heptyne, 1-hexyne, or phenylacetylene reacts with 0.5 mole of ethylmagnesium chloride in 250 ml. of ethyl ether, part of the acetylenic Grignard reagent is precipitated as a white solid.

The dimagnesium Grignard reagent of acetylene itself was also prepared by Iotsitch²⁰¹ by the passage of acetylene into an ethereal solution

¹⁹⁸Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 34, 241-2 (1902); *Bull. soc. chim.*, [3], 30, 209 (1903).

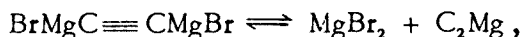
¹⁹⁹Meyer and Streuli, *Helv. Chim. Acta*, 20, 1179-83 (1937).

²⁰⁰Kroeger and Nieuwland, *J. Am. Chem. Soc.*, 58, 1861-3 (1936).

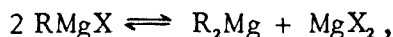
²⁰¹Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 34, 242-4 (1902); *Bull. soc. chim.*, [3], 30, 210 (1903).

of ethylmagnesium bromide, and was found to react normally with carbon dioxide, ketones, and aldehydes.

According to Kleinfeller²⁰² the dimagnesium Grignard reagent of acetylene ($\text{BrMgC}\equiv\text{CMgBr}$ or the corresponding diiodide), when prepared in ether solution is an ether-insoluble, ether-free oil that undergoes characteristic Grignard reactions. On long standing (three to four weeks) it becomes a crystalline solid which still reacts with water to liberate acetylene, but which no longer reacts like a Grignard reagent with the usual organic or inorganic reactants. The change is described as

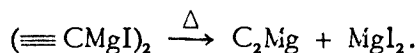


which Kleinfeller regards as a special case of the Schlenk equilibrium,²⁰³



which in this instance lies completely to the right.

An analogous observation has been made by Durand,²⁰⁴ who cautiously heated ethynylmagnesium iodide to the point of incipient carbonization. When the cooled mass was extracted with ether, magnesium iodide was removed, and a white, porous, amorphous, iodine-free residue remained. This, when treated with water, liberated acetylene. The reaction postulated is:



A method advocated as convenient for the preparation of large quantities of ethynylmagnesium bromide [$(\equiv\text{CMgBr})_2$] is described by Kleinfeller²⁰⁵ essentially as follows. Dry acetylene is led into ethereal ethylmagnesium bromide until ethane evolution ceases and the acetylenic Grignard reagent forms a film-covered dark, heavy layer. It is expedient to conserve gas by employing a series of interconnected absorption vessels. For a series of five flasks, each containing ethylmagnesium bromide from 36.3 g. of ethyl bromide, about forty-eight hours is required for complete conversion.

Oddo²⁰⁶ claimed to have prepared the monomagnesium Grignard reagent of acetylene by saturating an ethereal solution of phenylmagnesium bromide with acetylene. Iotsitch²⁰⁷ was unable to confirm the presence of the monomagnesium compound under the conditions apparently described in the abstract of Oddo's paper, but did obtain a mixture of propargyl al-

²⁰² Kleinfeller, *Ber.*, 62B, 2736-8 (1929).

²⁰³ Schlenk and Schlenk, *Ber.*, 62B, 920-4 (1929). See Chapter IV, Constitution and Dissociation of the Grignard Reagent.

²⁰⁴ Durand, *Bull. soc. chim.*, [4], 35, 944-5 (1924).

²⁰⁵ Kleinfeller, *J. prakt. Chem.*, [2], 119, 66-73 (1928).

²⁰⁶ Oddo, *Gazz. chim. ital.*, [2], 34, 429-36 (1904); *Bull. soc. chim.*, [3], 36, 682 (1906).

²⁰⁷ Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 38, 252-3 (1906); *Bull. soc. chim.*, [4], 4, 981 (1908).

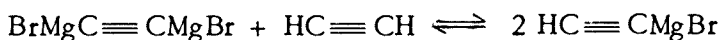
cohol and the acetylenic glycol when he passed a current of acetylene through the reaction flask during the five hours necessary for completion of the reaction between trioxymethylene and the dimagnesium compound. Analogous results were obtained with 3-methylcyclohexanone and menthone.

By saturating an ethereal solution of phenylmagnesium bromide with acetylene, then decomposing the resultant acetylenic Grignard compounds with water, and measuring the volume of acetylene evolved, Salkind and Rosenfeld²⁰⁸ estimated that the yield of monomagnesium compound so obtained could not exceed 36 percent. When passage of acetylene through the solution was continued for thirty hours, the indicated yield of monomagnesium compound was about 51 percent. Under the same conditions, except that brisk refluxing of the ethereal solution was maintained throughout, the indicated yield of monomagnesium compound approximated 100 percent.

Lespieau²⁰⁹ prepared an acetylenic Grignard reagent which he believed to consist principally of the dimagnesium compound by passing ether-saturated acetylene into a dilute ethereal solution of ethylmagnesium bromide for forty to eighty hours. Dropwise addition of a calculated 0.3 equivalent of aldehyde or ketone dissolved in a threefold volume of ether resulted in yields up to 25 percent of alcohols (as distinguished from glycols). Lespieau attributed alcohol formation to partial reaction in the sense:



Krestinski and Marjin²¹⁰ saturated an ice-salt-cooled ethereal solution of the dimagnesium Grignard compound with acetylene, added isobutyraldehyde and allowed the mixture to stand overnight. They attribute the alcohol obtained $[\text{HC}\equiv\text{CCH}(i\text{-C}_3\text{H}_7)\text{OH}]$ to the equilibrium:



According to Grignard *et al.*,²¹¹ a yield of 95 percent of the dimagnesium Grignard reagent may be obtained by saturating an ethereal solution of ethylmagnesium bromide, prepared in the usual manner, with acetylene. When such a solution is further treated with acetylene under an excess pressure of a half atmosphere at 45° for about four hours, an 85 percent yield of the monomagnesium compound is obtained. Carbonation leads to propiolic acid in about 78 percent yield. Treatment of a similar solution

²⁰⁸ Salkind and Rosenfeld, *Ber.*, 57B, 1690-2 (1924).

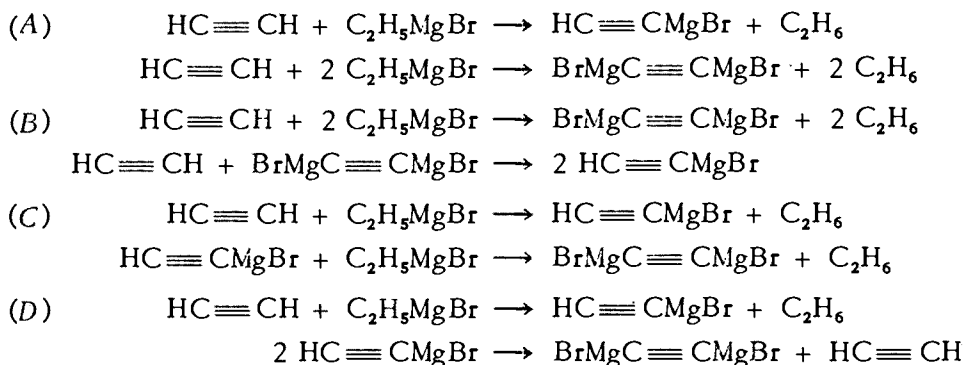
²⁰⁹ Lespieau, *Bull. soc. chim.*, [4], 39, 991-4 (1926).

²¹⁰ Krestinski and Marjin, *Ber.*, 60B, 1866-9 (1927).

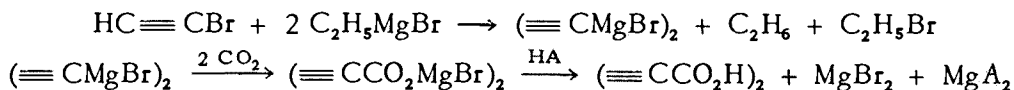
²¹¹ Grignard, Lapayre, and Tchéoufaki, *Compt. rend.*, 187, 517-20 (1928). See also: Tchéoufaki, *Contr. Inst. Chem. Nat. Acad. Peiping*, 1, 127-52 (1934); *Chem. Zentr.*, 1937, II, 2982.

of dimagnesium compound with acetylene under one-half atmosphere excess pressure at -10° for about three-quarters hour gives a nearly quantitative yield of monomagnesium compound which, in turn, reacts with allyl bromide to give allylacetylene in 75 percent yield.

Kleinfeller and Lohmann²¹² have reviewed earlier work on the monomagnesium compound and have made a kinetic study of the reactions involved. They conclude that the entire process may be described by the concurrent and mutually independent reactions A and the successive reactions B, C and D.

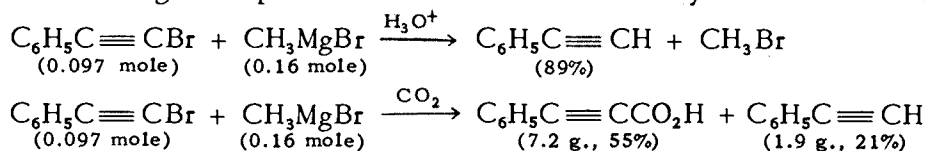


That acetylenic Grignard reagents may be prepared by halogen replacement as well as by hydrogen replacement has been demonstrated by Iotsitch,²¹³ who treated bromoacetylene with ethylmagnesium bromide and obtained a Grignard reagent which yielded acetylenedicarboxylic acid upon carbonation and subsequent acid hydrolysis.



Treatment of a Grignard reagent so prepared with acetone resulted in a 60 percent yield of the expected glycol; with "methylcyclohexanone" a 75 percent yield of glycol was obtained. Diiodoacetylene also yielded ethynylmagnesium bromide when treated with ethylmagnesium bromide.

Similar halogen displacement has been observed by Kharasch *et al.*²¹⁴



These halogen replacement reactions are undoubtedly more closely related to the analogous hydrogen replacements than to the free-radical functional exchanges (*q.v.*, Chapter XVI.)

²¹² Kleinfeller and Lohmann, *Ber.*, 71B, 2608-13 (1938).

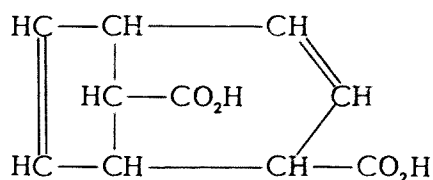
²¹³ Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 36, 1545-51 (1904); *Bull. soc. chim.*, [3], 36, 177 (1906).

²¹⁴ Kharasch, Lambert, and Urry, *J. Org. Chem.*, 10, 298-306 (1945).

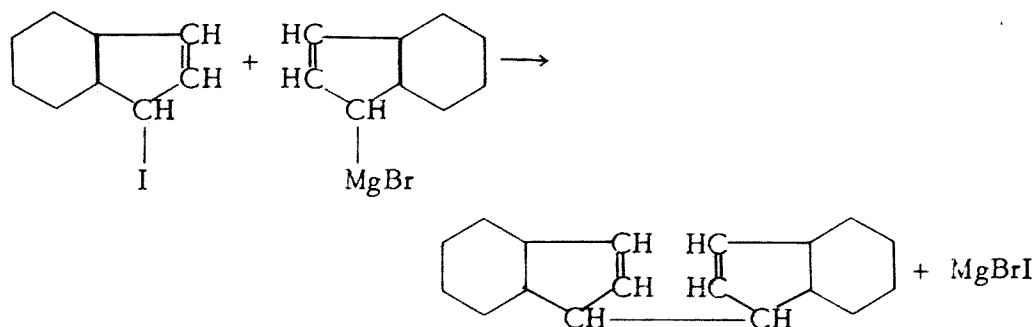
Non-acetylenic hydrocarbons and their derivatives*

Cyclopentadiene, indene, and fluorene. Grignard and Courtot²¹⁵ found that cyclopentadiene, indene, and fluorene all react with ordinary Grignard reagents in a manner similar to that of the 1-alkynes.

Cyclopentadiene reacts slowly with ethylmagnesium bromide in boiling ether, reaction being incomplete for one-mole quantities at the end of twelve hours. If the ether be partially replaced by thiophene-free benzene, reaction is complete in five or six hours at 60°. Many cyclopentadiene derivatives have, like cyclopentadiene itself, a strong tendency to dimerize. Thus the acid obtained (in *ca.* 60 percent yield) by carbonation of cyclopentadienylmagnesium bromide is the dimeric acid, probably



Indene requires a somewhat higher temperature (90–100°) for reaction with ethylmagnesium bromide. In toluene solution at 100°, reaction is substantially complete (for one-mole quantities) in about ten hours. Treatment of α -indenylmagnesium bromide with iodine leads, not to α -indenyl iodide, but to α,α' -biindenyl, possibly because of the great reactivity of the iodide toward Grignard reagents, although this course of reaction is not unique,²¹⁶ and may have another mechanism.



Cyanogen bromide yields the *alpha* bromide, but cyanogen chloride leads to α -cyanoindene. Carbonation leads to the α -carboxylic acid in 86 percent yield.

* Although this section is concerned primarily with reactions of true hydrocarbons, the classification is intended to include other displacements of carbon-linked hydrogen.

²¹⁵Grignard and Courtot, (a) *Compt. rend.*, 152, 272–4 (1911); *Chem. Zentr.*, 1911,1, 885; (b) *Compt. rend.*, 152, 1493–5 (1911); *Chem. Zentr.*, 1911,II, 148; (c) *Compt. rend.*, 158, 1763–6 (1914); *Chem. Zentr.*, 1914,II, 397; (d) *Compt. rend.*, 160, 500–4 (1915); *Chem. Zentr.*, 1915,II, 406; (e) Courtot, *Ann. chim.*, [9], 4, 58–136, 157–224 (1915).

²¹⁶See: Datta and Mitter, *J. Am. Chem. Soc.*, 41, 287–92 (1919).

9-Fluorenylmagnesium bromide was prepared from fluorene and ethylmagnesium bromide held at 135–140° in xylene solution for twelve hours. A yield of 65 percent of the expected tertiary alcohol is claimed by Courtot^{215b} upon treatment of the Grignard reagent with benzophenone. Miller and Bachman²¹⁷ reported inability to repeat Courtot's preparation of fluorenylmagnesium bromide in satisfactory yields and add that "invariably about 65 percent of the original fluorene was recovered unchanged and the amount of ethane evolved corresponded to only 32 percent reaction." Young and Roberts²¹⁸ report that neither fluorene nor quinaldine show any evidence of the presence of "active" hydrogen during several hours reflux with ethyl ethereal butenylmagnesium bromide. However, the temperature at which the experiment is conducted is unquestionably an important factor in the success or failure of attempts to displace hydrogen from hydrocarbons, and it may be that the nature of the specific Grignard reagent employed is also significant. Zerewitinoff²¹⁹ found that when a pyridine solution of fluorene is added to an excess of amyl ethereal methylmagnesium iodide at room temperature no reaction takes place; at 85° methane corresponding to 1.04 equivalent of "active" hydrogen is liberated in the course of five minutes. Indene, 9-phenylfluorene, 13-dibenzo[*a,i*]fluorene, and 13- α -naphthyl-13-dibenzo[*a,i*]fluorene are similar to fluorene in their behavior.

According to Gilman *et al.*,²²⁰ triphenylmethane does not react appreciably with ethylmagnesium bromide either in boiling ethyl ethereal solution or in ether-toluene solution at 80° for seven hours. Diphenylmethane is said to be similarly inert.

Phenylacetic acid. Grignard²²¹ observed that, although most carboxylic acids react with an excess of organomagnesium halide to form a tertiary alcohol, phenylacetic acid constitutes an exception in that the second molecule of Grignard reagent enters into a double displacement reaction in which one of the *alpha* hydrogen atoms of the acid is involved.



Incidentally, Klages²²² reports that the corresponding ethyl ester reacts "normally" with methyl- or ethylmagnesium iodide to yield the expected tertiary alcohol. "Normal" reactions of the ethyl ester with phenylmagnesium bromide,²²³ benzylmagnesium chloride^{223, 224} and benzylmag-

²¹⁷ Miller and Bachman, *J. Am. Chem. Soc.*, 57, 766–71 (1935).

²¹⁸ Young and Roberts, *J. Am. Chem. Soc.*, 68, 1472–5 (1946).

²¹⁹ Zerewitinoff, *Ber.*, 45, 2384–9 (1912).

²²⁰ (a) Gilman and Peterson, *Rec. trav. chim.*, 48, 247–50 (1929); (b) Gilman and Leermakers, *ibid.*, 48, 577–9 (1929).

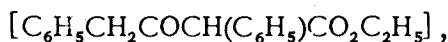
²²¹ Grignard, *Bull. soc. chim.*, [3], 31, 751–7 (1904).

²²² Klages, *Ber.*, 37, 1721–6 (1904).

²²³ Klages and Heilmann, *Ber.*, 37, 1447–57 (1904).

²²⁴ Austin and Johnson, *J. Am. Chem. Soc.*, 54, 647–60 (1932).

nesium bromide²²⁵ have also been reported. Conant and Blatt,²²⁶ however, have found that the ester reacts with isopropylmagnesium bromide to give a 94 percent yield of α -phenylphenylacetoacetic ester



together with "saturated gas" (undoubtedly propane). Reaction with isopropylmagnesium chloride is similar.²²⁷ These Claisen (or acetoacetic ester-type) condensations are unquestionably consequences of ester enolization and reaction of the enolate with more ester.

Schlenk *et al.*²²⁸ maintain (and with reason, in the opinion of the present authors) that the reaction of a salt of phenylacetic acid with a Grignard reagent is essentially an enolization. The resultant enolate is by no means unique in behaving like a true Grignard reagent; the enolate of acetomesitylene furnishes a similar example,²²⁹ though one not so extensively investigated. The behavior of the enolates of the methyl and ethyl dineopentylcarbinyl ketones is also illustrative.²³⁰

Ivanoff *et al.*²³¹ have carried out many normal Grignard reactions with reagents of the types $\text{C}_6\text{H}_5\text{CH}(\text{MgBr})\text{CO}_2\text{MgCl}$ and $\text{C}_6\text{H}_5\text{CH}(\text{MgBr})\text{CO}_2\text{Na}$. Ivanoff and Spassoff^{231a} report, for example, a 62.5 percent yield of phenylmalonic acid by treatment of a salt of phenylacetic acid with ethylmagnesium bromide, followed by carbonation and hydrolysis.

*Sulfones.** Although Hepworth and Clapham^{231.1} had reported that phenyl benzyl sulfone is recovered, apparently unchanged, after high-temperature treatment with methylmagnesium iodide and hydrolysis of the reaction mixture, Kohler and Potter^{231.2} found that phenethyl *p*-tolyl sulfone and β,β -diphenylethyl *p*-tolyl sulfone have at least one "active" hydrogen atom each, displaceable at 50–75°. Methyl *p*-tolyl sulfone liberates methane slowly from methylmagnesium iodide at room temperature, and has at least two "active" hydrogen atoms, for its halomagnesium derivative yields dibenzoylmethyl *p*-tolyl sulfone upon treatment with benzoyl chloride. Kohler and Potter^{231.3} also obtained from bis-(*p*-tolylsulfonyl)-

²²⁵Sachs and Loevy, *Ber.*, 36, 3236 (1903).

²²⁶Conant and Blatt, *J. Am. Chem. Soc.*, 51, 1227–36 (1929).

²²⁷Ivanoff and Spassoff, *Bull. soc. chim.*, [4], 49, 375–7 (1931).

²²⁸Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135–54 (1931).

²²⁹Fuson, Fugate, and Fisher, *J. Am. Chem. Soc.*, 61, 2362–5 (1939).

²³⁰(a) Whitmore and Randall, *J. Am. Chem. Soc.*, 64, 1242–6 (1942); (b) Whitmore and Lester, *J. Am. Chem. Soc.*, 64, 1247–51, 1251–3 (1942).

²³¹Ivanoff and Spassoff, (a) *Bull. soc. chim.*, [4], 49, 19–23 (1931); (b) [4], 49, 371–5 (1931); (c) [4], 49, 375–7 (1931); (d) [4], 49, 377–9 (1931); (e) Ivanoff, Mihova, and Christova, *ibid.*, [4], 51, 1321–5 (1932); (f) Ivanoff and Nicoloff, *ibid.*, [4], 51, 1325–31, 1331–7 (1932).

*See also Chapter XXI, Sulfones.

^{231.1}Hepworth and Clapham, *J. Chem. Soc.*, 119, 1188–98 (1921).

^{231.2}Kohler and Potter, *J. Am. Chem. Soc.*, 57, 1316–21 (1935).

^{231.3}Kohler and Potter, *J. Am. Chem. Soc.*, 58, 2166–30 (1936).

methane by hydrogen displacement a bromomagnesium derivative which, upon treatment with benzoyl chloride, yielded α,α -bis-(*p*-tolylsulfonyl)-acetophenone. Gilman and Webb,^{231.4} obtained an acidic gum by successive treatment of ethyl phenyl sulfone with ethylmagnesium bromide and carbon dioxide. Field^{231.5} has treated methyl phenyl sulfone successively with ethylmagnesium bromide and benzaldehyde, obtaining 1-phenyl-2-phenylsulfonylethanol.

Undoubtedly the halomagnesium derivatives arising from sulfone hydrogen displacement are analogous to the enolates capable of functioning as true Grignard reagents.

Aromatic ethers. In view of the relatively few cases and the rather meagre yields so far reported, the replacement of an *ortho* hydrogen atom of an aromatic ether by an —MgX group can scarcely be said to rank as a general preparative method for Grignard reagents. Certainly the hydrogen atoms so displaced are not of the type ordinarily designated as "active." Probably the reactions involved represent, as Challenger and Miller²³² suggest, one of the possible types of thermal decomposition of oxonium complexes. (See Ether Cleavage by Grignard Reagents, Chapter XVI).

In an example described by Challenger and Miller (*loc. cit.*²³²), 2 g. of magnesium was allowed to react with 9 g. of ethyl bromide in 120 ml. of ethyl ether; 25 g. of phenetole was then added, the ethyl ether was removed by distillation, and the residue was heated under reflux at 200° for five hours. Treatment of the resultant solution with mercuric bromide yielded 24 percent of *o*-bromomercuriphenetole.

Similar treatment of anisole at 180° for eight hours, and subsequent mercuration yielded 9–11 percent of *o*-bromomercurianisole. Substitution of isopropylmagnesium chloride for ethylmagnesium bromide in an analogous treatment of anisole led to a 3 percent yield of the *o*-mercuri compound.

In an example described by Gilman and Haubein,²³³ a filtered ethylmagnesium bromide solution, prepared from 0.4 mole of ethyl bromide, was combined with a solution of 0.1 mole of dibenzofuran in 50 ml. of ether; the ether was removed by distillation, and the residue was heated at 165° for six hours. Subsequent carbonation led to a 5 percent yield of the 4-carboxylic acid.

2-Methylbenzothiazole. Courtot and Tchelitcheff²³⁴ report that when 2-methylbenzothiazole is treated with ethylmagnesium bromide an "ac-

^{231.4} Gilman and Webb, *J. Am. Chem. Soc.*, 71, 4062–6 (1949).

^{231.5} Field, *J. Am. Chem. Soc.*, 74, 3919–21 (1952).

²³² Challenger and Miller, *J. Chem. Soc.*, 1938, 894–9.

²³³ Gilman and Haubein, *J. Am. Chem. Soc.*, 67, 1033–4 (1945).

²³⁴ Courtot and Tchelitcheff, *Compt. rend.*, 217, 201–3 (1943); *Chem. Abstr.*, 38, 5502 (1944).

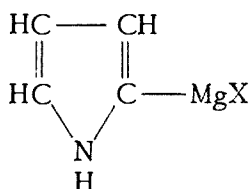
tive" hydrogen atom of the methyl group is displaced, with formation of a Grignard reagent that, upon carbonation, yields 2-benzothiazoleacetic acid. Treatment of the reagent with acetone or benzophenone yields the expected tertiary alcohol.

Thiophthene. Treatment of thiophthene with ethylmagnesium bromide in dimethylaniline, and subsequent carbonation of the reaction mixture is reported to yield "thiophthenecarboxylic acid" (m.p., 247°).²³⁵

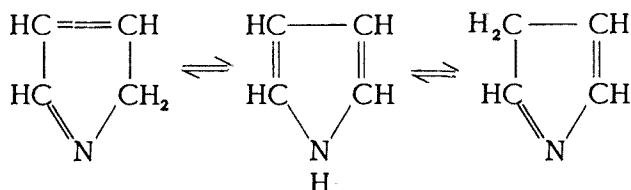
Nitrogen heterocycles with "active" hydrogen. Oddo²³⁶ discovered that methylmagnesium iodide reacts with pyrrole in ether solution to form a pyrrylmagnesium iodide which may be precipitated from ether as a pyridine complex $(C_5H_5N)_2 \cdot C_4H_4NMgI$. By carbonation of an ethereal solution of pyrrylmagnesium iodide, he obtained the α -carboxylic acid in 25-30 percent yield. Somewhat better yields (ca. 40 percent) have since been reported by others.²³⁷

Oddo further reported that pyrrylmagnesium iodide reacts with chloroformic ester^{238a} to form the α -carbethoxy derivative, and with acyl chlorides^{238b} to form the α ketones in yields of 50-60 percent for the aliphatic acyl chlorides, and as great as 80 percent for the aromatic acyl chlorides.

In general, the pyrrylmagnesium halides react as though they had the constitution



This, of course, is only one of the chemical peculiarities of pyrrole which have led to the assumption that it is tautomeric with the α - and β -pyrrolenines,²³⁹ whose formal resemblance to cyclopentadiene is obvious.



²³⁵Challenger, Clapham, and Emmott, *J. Inst. Petroleum*, 34, 922-9 (1948); *Chem. Abstr.*, 43, 4666 (1949).

²³⁶Oddo, *Gazz. chim. ital.*, 39, I, 649-59 (1909); *Chem. Zentr.*, 1909, II, 914.

²³⁷(a) Gilman and Pickens, *J. Am. Chem. Soc.*, 47, 245-54 (1925); (b) McCay and Schmidt, *ibid.*, 48, 1933-9 (1926).

²³⁸Oddo, (a) *Gazz. chim. ital.*, 40, II, 353-67 (1910); *Chem. Zentr.*, 1911, I, 322; (b) *Ber.*, 43, 1012-21 (1910).

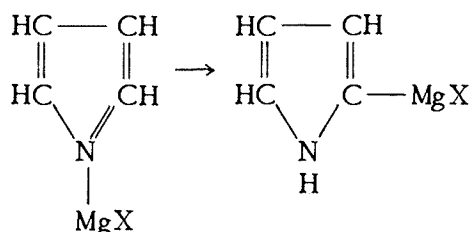
²³⁹See: Fischer and Orth, "Die Chemie des Pyrrole," Band I, Leipzig, 1934, p. 7.

Nenitzescu²⁴⁰ has argued that because the pyrrolylmagnesium halides give positive color reactions with Michler's ketone they should be formulated as carbon-linked Grignard reagents. (Nitrogen-linked Grignard reagents, including the indolyl, react negatively to this test.)

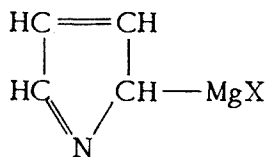
Gilman and Heck,²⁴¹ however, point out that in the presence of acetic acid and iodine, which are used to develop the Michler's ketone color test, pyrrole produces a bluish coloration which might be mistaken for a positive Grignard reagent color test.

The arguments, pro and con, are equally beside the point, for if a pyrrolylmagnesium halide, regardless of its constitution, is capable of reacting with a carbonyl group to establish a carbon-to-carbon bond (as there is ample evidence that it is) there is no reason why it should not react with Michler's ketone to form the leuco base of the triphenylmethane dye upon which the color test is based.

Gilman prefers the nitrogen-linked Grignard reagent formulation and maintains that the known reactions of a pyrrolylmagnesium halide so formulated are entirely analogous to the comparable reactions of the sodium enolate of acetoacetic ester. He bases his argument chiefly on the fact that pyrrole, like indole, skatole, and carbazole, shows only one active hydrogen atom when submitted to Zerewitinoff analysis,²⁴² and contends that a rearrangement of the type



should lead to the indication of at least two active hydrogen atoms. This argument, however, loses a good deal of whatever cogency it may possess when the Grignard reagent is formulated as an α -pyrrolenine derivative.



The reactions of a pyrrolylmagnesium halide might be adequately accounted for by formulation as a mixture of derivatives of the three hypothetical tautomeric forms, with the α -pyrrolenine derivative in marked preponderance, or of considerably greater reactivity than the other forms.

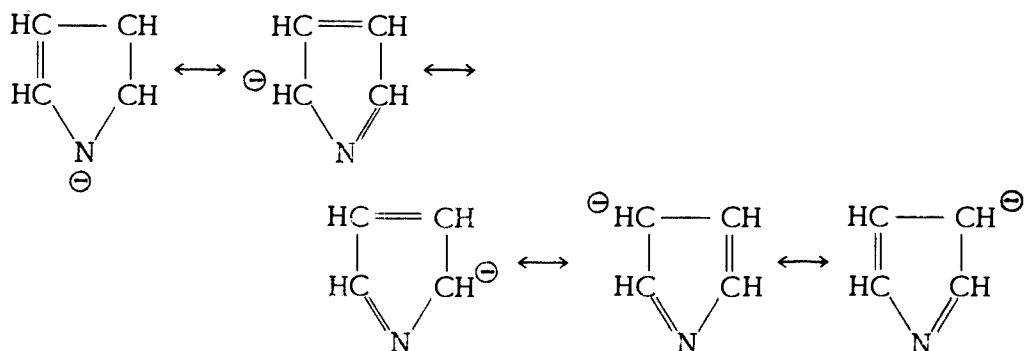
Alternatively the Grignard reagent might be formulated as an ionic,

²⁴⁰ Nenitzescu, *Bull. soc. chim. Romania*, 11, 130-4 (1930); *Chem. Abstr.*, 24, 2458 (1930).

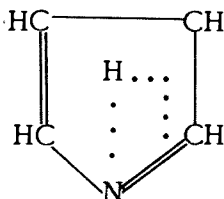
²⁴¹ Gilman and Heck, *J. Am. Chem. Soc.*, 52, 4949-54 (1930).

²⁴² Oddo, *Ber.*, 44, 2048-52 (1911). See also: Gilman and Heck, *loc. cit.*²⁴¹

though not necessarily highly dissociated compound $[(C_4H_4N)^-(MgBr)^+]$, with a resonant anion in which, for reasons perhaps not altogether obvious, the *alpha* position is that favored for electrophilic attack.

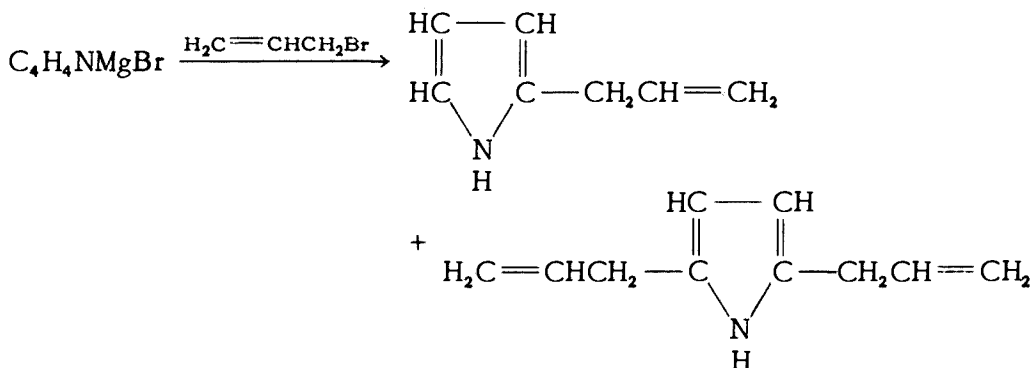


Oddo²⁴³ has suggested a "mesohydric" formulation for pyrrole and a corresponding formulation for the Grignard reagents, which he believes accounts satisfactorily for their behavior.



In any event, the reaction of a pyrrolylmagnesium halide as a nitrogen-linked Grignard reagent, with subsequent rearrangement of the product would seem to be definitely ruled out, for some cases at least, by the high temperature necessary to effect such a rearrangement. de Jong,²⁴⁴ for example, confirmed the preparation of 2-ethylpyrrole from pyrrolylmagnesium bromide and ethyl bromide in ether solution by Hess *et al.*,²⁴⁵ but had to employ a temperature of about 650° to effect the rearrangement of *N*-ethylpyrrole to 2-ethylpyrrole.

Hess²⁴⁵ has explained the double substitution reactions sometimes observed, like, for instance, that with allyl bromide,

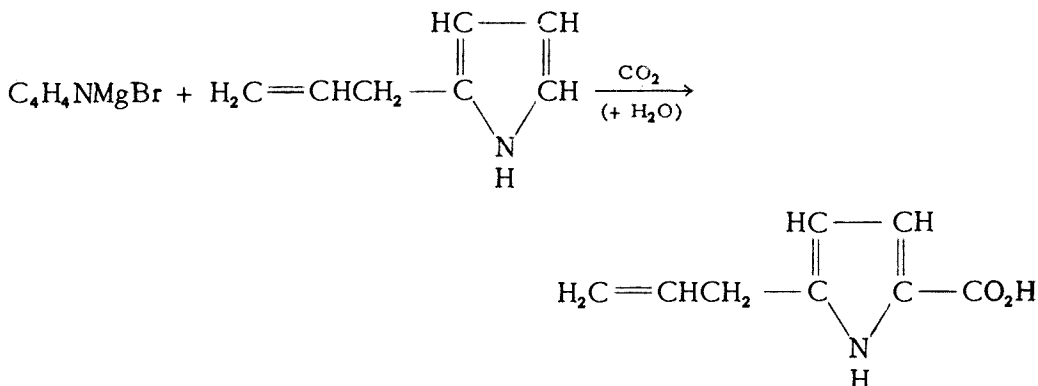


²⁴³ Oddo, *Gazz. chim. ital.*, 64, 584-94 (1934); *Chem. Zentr.*, 1935, I, 393.

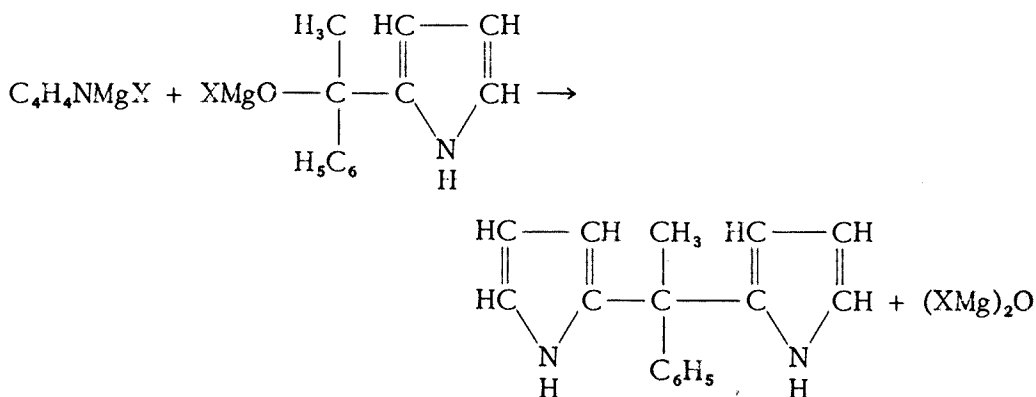
²⁴⁴ de Jong, *Rec. trav. chim.*, 48, 1029-30 (1929).

²⁴⁵ Hess, Wissing, and Suchier, *Ber.*, 48, 1865-84 (1915).

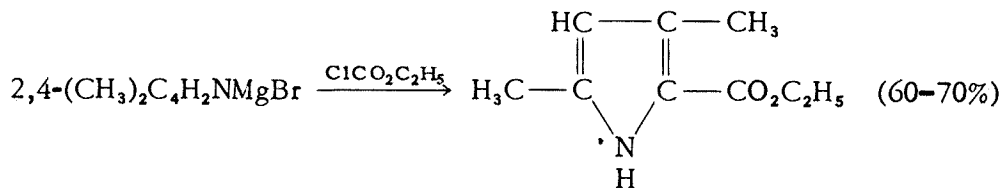
as resulting from interaction of the original pyrrol Grignard reagent with some of the product first formed, and has supported his interpretation by treating pyrrolmagnesium bromide with 2-allylpyrrole and then carbonating the resultant product to obtain 5-allylpyrrole-2-carboxylic acid.



According to Oddo and Perotti,²⁴⁶ the pyrrol Grignard reagent reacts with acetophenone to form, chiefly, the di- α -pyrrolmethane, with very little of the carbinol ordinarily to be expected. This observation suggests that the pyrrol reagent is capable of undergoing the rather unusual reaction:



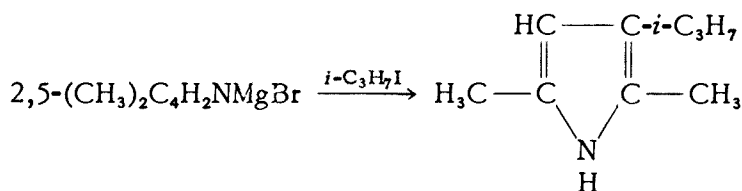
The mono- α -alkylated pyrroles form Grignard reagents which react with the introduction of substituents at the previously unsubstituted α position.²⁴⁷



²⁴⁶ Oddo and Perotti, *Gazz. chim. ital.*, 60, 13-21 (1930); *Chem. Zentr.*, 1930, I, 3051; *Chem. Abstr.*, 24, 3875 (1930).

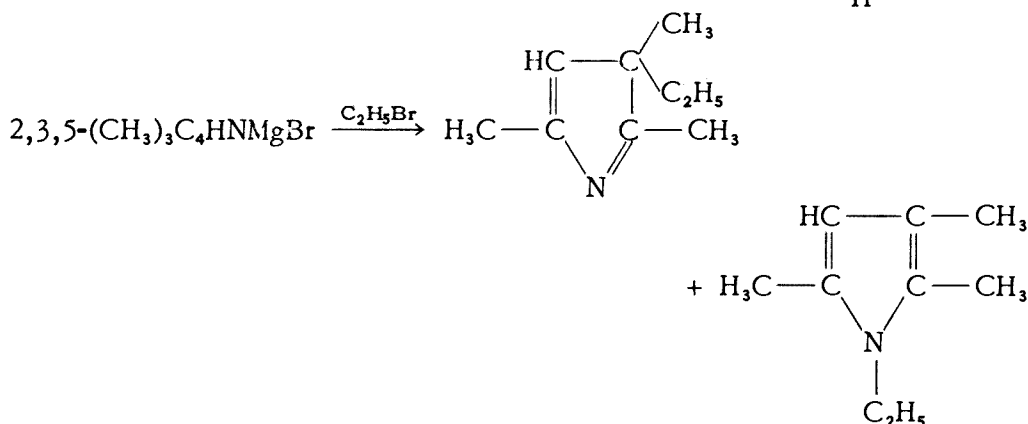
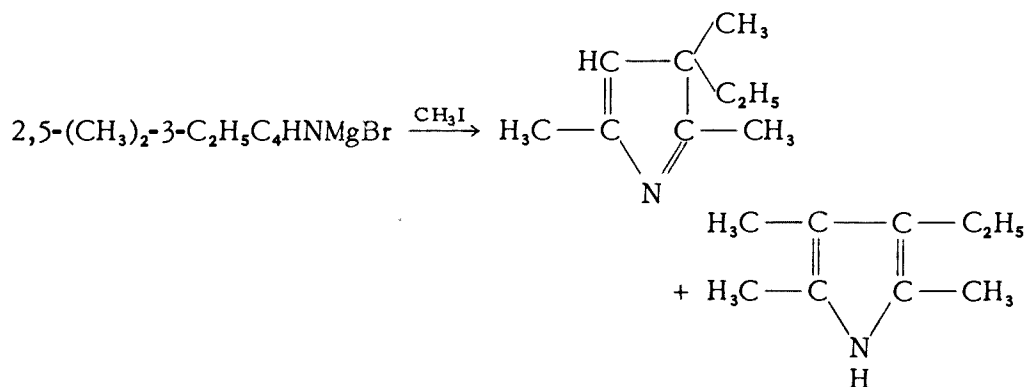
²⁴⁷ Fischer, Weiss, and Schubert, *Ber.*, 56B, 1194-202 (1932); Fischer, *Organic Syntheses*, Coll. Vol. II, pp. 198-200, 1943. See also: Fischer, Baumann, and Riedl, *Ann.*, 475, 205-41 (1921).

Reaction of a Grignard reagent prepared from an α,α' -dialkylpyrrole results in substitution at one of the *beta* positions.²⁴⁸

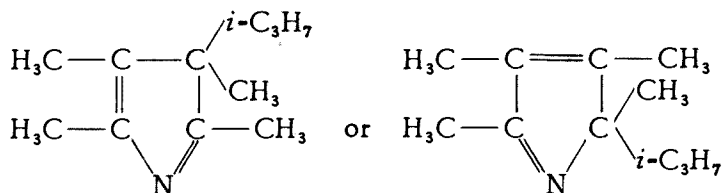


+ two isomeric diisopropylpyrrolenines

Previous substitution at a *beta* position does not appear to constitute a serious impediment to further *beta*-substitution.²⁴⁹



According to Plancher and Tanzi (*loc. cit.*²⁴⁸), the Grignard reagent derived from 2,3,4,5-tetramethylpyrrole reacts with isopropyl iodide to form a tetramethylisopropylpyrrolenine of undetermined constitution, probably:

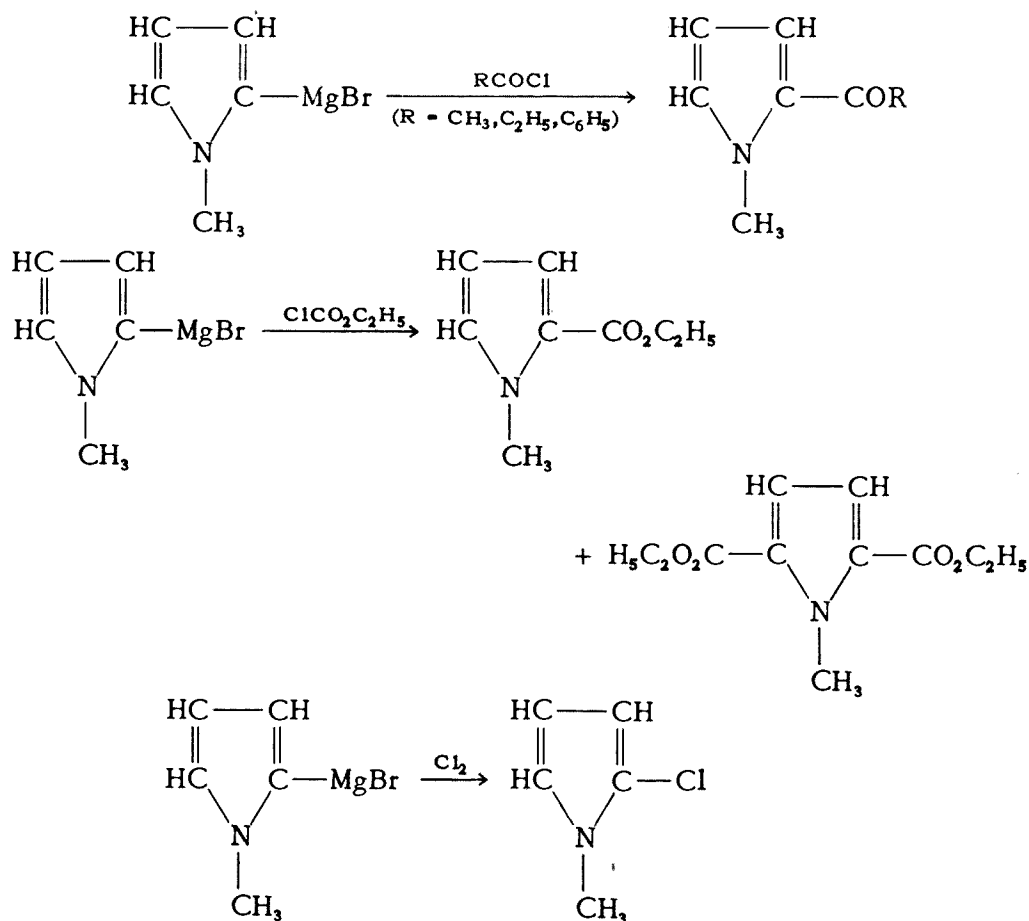


²⁴⁸ Plancher and Tanzi, *Atti accad. Lincei*, [5], 23, II, 412-7 (1914); *Chem. Zentr.*, 1915, I, 743; *Chem. Abstr.*, 9, 1477 (1915).

²⁴⁹ Hess, Wissing, and Suchier, *Ber.*, 48, 1865-84 (1915).

Offhand prediction might lead to the expectation that *N*-substituted pyrroles would prove unreactive toward Grignard reagents, for they neither possess the "active" >NH grouping nor can they be formulated as pyrrolenines. As a matter of fact, however, Hess and Wissing²⁵⁰ have found that *N*-methylpyrrole reacts so vigorously with ethylmagnesium bromide in ethereal solution that the reaction must be moderated by cooling. This phenomenon is probably satisfactorily explicable as the result of decomposition, with rearrangement, of an unstable tertiary amine-Grignard reagent complex. This interpretation is analogous to that advanced to account for the formation of an aromatic Grignard reagent by interaction of an aromatic ether with ethylmagnesium bromide, but with the difference that, whereas the one process takes place spontaneously, the other is only partial under "forced conditions."

The *N*-methylpyrrolmagnesium bromide so formed reacts with the usual Grignard reagent co-reactants to form α -substituted *N*-methylpyrroles.



Other examples of the reactions of pyrrol- and substituted pyrrolmagnesium halides will be found in the appropriate tabulations.

Oddo²⁵¹ discovered that indole, like pyrrole, reacts with one equivalent

²⁵⁰ Hess and Wissing, *Ber.*, 47, 1416-28 (1914).

²⁵¹ Oddo, *Gazz. chim. ital.*, 41, I, 221-34 (1911); *Chem. Zentr.*, 1911, I, 1852.

of ethylmagnesium iodide to liberate ethane and to form a Grignard reagent that can be precipitated from ether solution in the form of a pyridine complex, $(C_5H_5N)_2 \cdot C_8H_6NMgI$.

The constitutions of the products formed by interaction of indolylmagnesium halides with the usual Grignard reagent co-reactants appear to vary (1) with the nature of the co-reactant and (2) with the experimental conditions.

Oddo (*loc. cit.*²⁵¹) reports that treatment of indolylmagnesium iodide with methyl iodide under "forced conditions" for fifteen hours yields skatole (the *beta* derivative), whereas twelve hours reflux in ether solution yields a mixture of *N*-methylindole and *N*-methylskatole.

Oddo and Sessa²⁵² found that the addition of acetyl chloride to a cooled ethereal solution of indolylmagnesium iodide yielded a mixture of the *beta* ketone and the *N*, β -diacetyl derivative. Propionyl chloride behaved similarly. Under the same conditions, *n*-butyryl chloride and benzoyl chloride gave the respective *beta* ketones. When allowed to react more energetically, benzoyl chloride gave the *N*, β -disubstitution product. Carbon dioxide and chloroformic ester were reported as yielding the *N* and the *alpha* derivatives, respectively, but this appears highly improbable in the light of the general behavior of indolylmagnesium halides and of the subsequent studies of Majima and Kotake.²⁵³ In an attempt to repeat the experiment of Oddo and Sessa, Majima and Kotake^{253b} treated an ice-salt-cooled solution of indolylmagnesium iodide with one equivalent of chloroformic ester. The mixture was then allowed to stand at room temperature for a time, and was finally heated on the steam bath for an hour. The product was a mixture of the β -carboxylic and *N*, β -dicarboxylic esters. The use of two equivalents of chloroformic ester and warming for two and a half hours on the steam-bath led to the *N*, β -dicarboxylic ester. One equivalent of chloroformic ester added at ice-bath temperature and stirred for an additional hour with ice-cooling gave the β -carboxylic ester in 78 percent yield.

Carbon dioxide is also reported^{253a} as yielding the β -carboxylic acid.

According to Majima and Kotake,^{253a, 254} anisole is a superior solvent for the preparation and subsequent reaction with carbonyl compounds of indolyl Grignard reagents. That this rather surprising observation cannot be attributed to the relatively high boiling point of anisole is indicated by the following summary of the description of one of their experiments. Magnesium turnings (2.4 g.) in 10 ml. of anisole were activated with a very small particle of iodine; then 16 g. (*ca.* 2 equivalents) of ethyl iodide was added dropwise with stirring. After completion of the reaction, an ice-salt bath was applied, and 5.9 g. of indole in 7-8 ml. of

²⁵² Oddo and Sessa, *Gazz. chim. ital.*, 41, 1, 234-48 (1911); *Chem. Zentr.*, 1911, I, 1853.

²⁵³ Majima and Kotake, (*a*) *Ber.*, 55B, 3865-72 (1922); (*b*) 63B, 2237-45 (1930).

²⁵⁴ Majima and Kotake, *Ber.*, 55B, 3859-65 (1922).

anisole was added gradually with vigorous stirring. In the cold 1.1–1.2 l. of ethane is evolved. When the reaction is carried out in ethyl ether, no gas is evolved in the cold; the reaction begins at room temperature and can be completed only by warming. Treatment of an anisole solution of indolylmagnesium iodide, prepared as described, with ethyl formate under cooling, gives the aldehyde in 40 percent yield. "Phenetole is also a satisfactory solvent for the foregoing series of reactions (though with smaller yield), but the aldehyde is not obtained in ethyl ether or *n*-amyl ether."

The final statement is apparently contradicted by Putochin.²⁵⁵ A summary of his account follows. Magnesium turnings (1.2 g.), activated with a little iodine, were covered with 10 ml. of benzene, and 1 ml. of ethyl ether was added. Ethyl iodide (8.5 g.) is then added dropwise with stirring. Reaction begins on warming to 70° on a water-bath, and is complete in two to three hours. The solution is cooled with snow, and 3 g. of indole in 8 ml. of benzene is added gradually with vigorous shaking. Ethane (*ca.* 600 ml.) is evolved. Intensive cooling with a snow-salt mixture during dropwise addition of 10 ml. of ethyl formate leads to *N*-formylindole (2.5 g.). Similar results are obtained in ethyl ether or *n*-amyl ether. Warming during the ester addition gives the *beta* aldehyde; results are similar in ethyl ether or *n*-amyl ether.

Other reactions of indolylmagnesium halides are described by: Majima and Shigematsu,²⁵⁶ Majima, Shigematsu, and Rokkaku,²⁵⁷ Majima and Hoshino,²⁵⁸ and Mingoia.²⁵⁹

As might be expected, the Grignard reagents derived from 2-methylindole behave like the indolylmagnesium halides themselves, the *beta* (3) position being the one favored for the introduction of substituents. Representative reactions are reported by: Oddo,²⁶⁰ Madelung and Tencer,²⁶¹ Majima *et al.* (*loc. cit.*²⁵⁸), Mingoia (*loc. cit.*²⁵⁹), Oddo and Tognacchini,²⁶² Oddo and Perotti,²⁶³ Hoshino,²⁶⁴ Hoshino and Tamura,²⁶⁵ and by Sanna and Chessa.²⁶⁶

²⁵⁵ Putochin, *Ber.*, 59B, 1987–98 (1926).

²⁵⁶ Majima and Shigematsu, *Ber.*, 57B, 1449–53 (1924).

²⁵⁷ Majima, Shigematsu, and Rokkaku, *Ber.*, 57B, 1453–6 (1924).

²⁵⁸ Majima and Hoshino, *Ber.*, 58B, 2042–6 (1925).

²⁵⁹ Mingoia, *Gazz. chim. ital.*, 56, 772–81 (1926); *Chem. Zentr.*, 1927, I, 2309.

²⁶⁰ Oddo, *Gazz. chim. ital.*, 43, II, 190–211 (1913); *Chem. Zentr.*, 1913, II, 1402.

²⁶¹ Madelung and Tencer, *Ber.*, 48, 949–53 (1915).

²⁶² Oddo and Tognacchini, *Gazz. chim. ital.*, 53, 271–5 (1923); *Chem. Zentr.*, 1923, III, 925; *Chem. Abstr.*, 17, 2883 (1923).

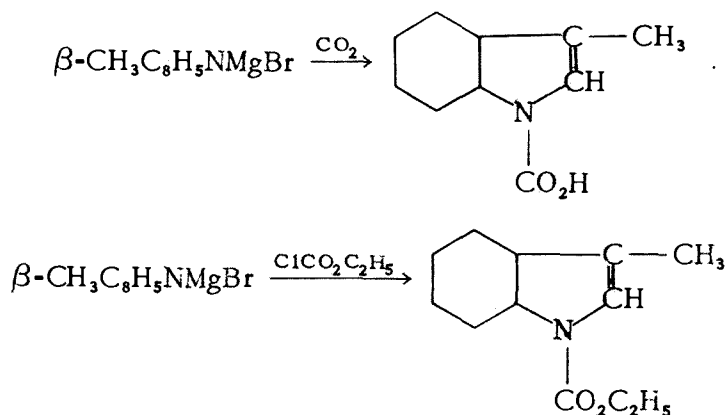
²⁶³ Oddo and Perotti, *Gazz. chim. ital.*, 60, 13–21 (1930); *Chem. Zentr.*, 1930, I, 3051; *Chem. Abstr.*, 24, 3875 (1930).

²⁶⁴ Hoshino, *Ann.*, 500, 35–42 (1932).

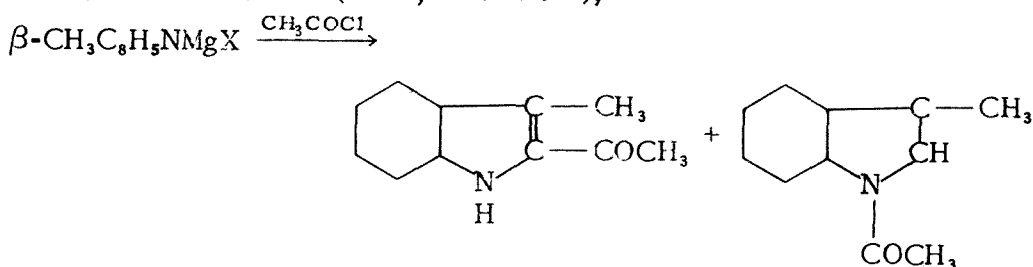
²⁶⁵ Hoshino and Tamura, *Ann.*, 500, 42–52 (1932).

²⁶⁶ Sanna and Chessa, *Gazz. chim. ital.*, 58, 121–7 (1928); *Chem. Zentr.*, 1928, I, 2505; *Chem. Abstr.*, 22, 2562 (1928).

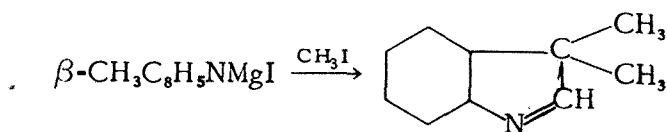
The Grignard reagents derived from skatole (3-methylindole) are reported to react to give *N*-substituted skatoles (Oddo²⁶⁷),



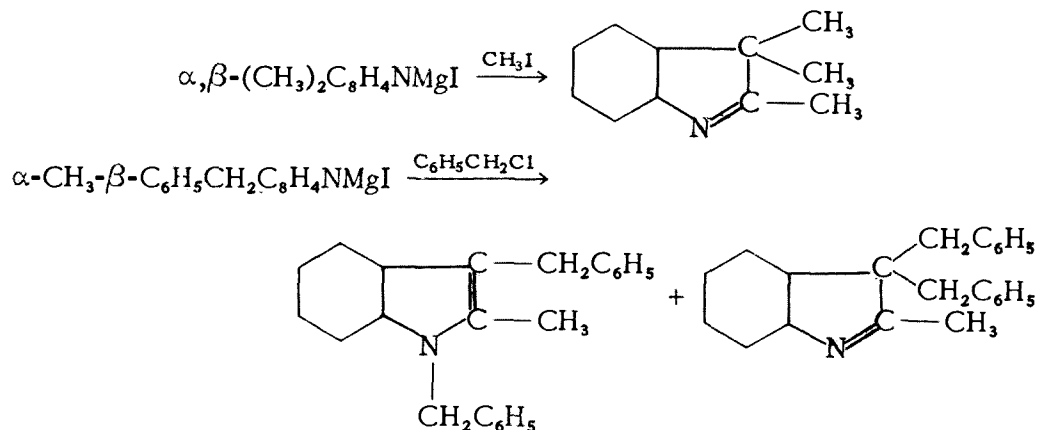
α -substituted skatoles (Oddo, *loc. cit.*²⁶⁷),



and indolenine derivatives (Hoshino, *loc. cit.*²⁶⁴),

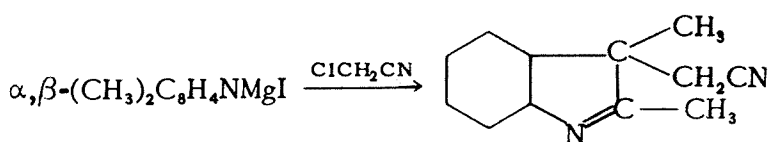


The α,β -disubstituted indolylmagnesium halides react to give both α,β,N -trisubstituted indoles and indolenine derivatives, according to Hoshino (*loc. cit.*²⁶⁴),



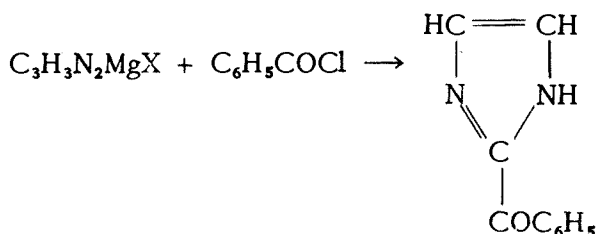
and Hoshino and Tamura (*loc. cit.*²⁶⁵).

²⁶⁷Oddo, *Gazz. chim. ital.*, 42, I, 361-75 (1912); *Chem. Zentr.*, 1912, II, 193.

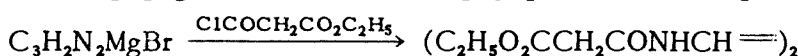
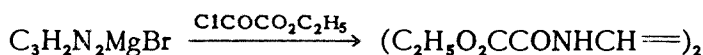
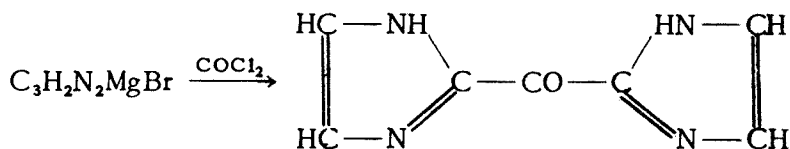
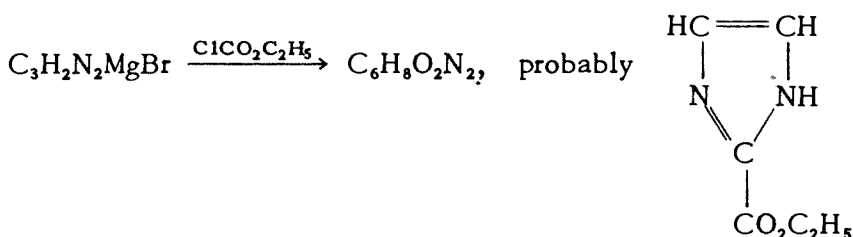


Other examples of the reactions of indolyl- and substituted indolyl-magnesium halides will be found in the appropriate tabulations.

Imidazole (glyoxaline) reacts with ethylmagnesium halides, liberating one equivalent of ethane, and forming imidazolyl Grignard reagents,²⁶⁸ which react somewhat like the pyrrol Grignard reagents, though they are apparently less reactive. Imidazolylmagnesium halide reacts with benzoyl chloride to give a benzoylated imidazole believed to be the μ (2) derivative.²⁶⁹



Imidazolylmagnesium bromide, with ether removed, treated on the water-bath for twenty hours with an excess of methyl iodide yields the N,μ -(1,2-) dimethyl derivative.²⁷⁰ The reaction with ethyl iodide is similar. Other reactions reported by Oddo and Mingoia (*loc. cit.*²⁷⁰) are as follows:



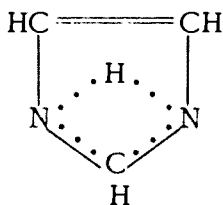
Oddo and Mingoia (*loc. cit.*²⁷⁰) did not obtain a stable acid upon treatment of imidazolylmagnesium bromide with carbon dioxide, imidazole be-

²⁶⁸ Oddo and Mingoia, *Gazz. chim. ital.*, 56, 958-60 (1926); *Chem. Abstr.*, 21, 1263 (1927).

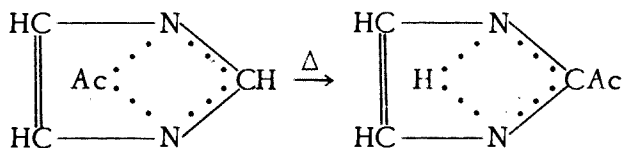
²⁶⁹ Oddo and Mingoia, *Gazz. chim. ital.*, 58, 573-84 (1928); *Chem. Abstr.*, 23, 1638 (1929).

²⁷⁰ Oddo and Mingoia, *Gazz. chim. ital.*, 58, 584-97 (1928); *Chem. Abstr.*, 23, 1638 (1929).

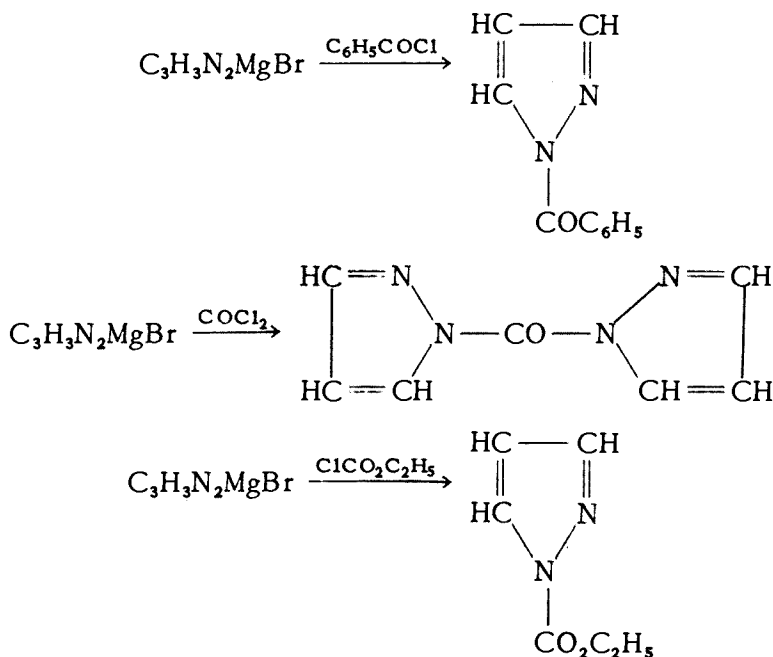
ing recovered. Analogous results were obtained with acetyl chloride, ethyl acetate and acetic anhydride. To account for this rather surprising unreactivity, they suggest a "mesohydric" structure for imidazole, with a corresponding structure for the Grignard reagent.



In a later paper, Oddo and Ingrassia²⁷¹ report that an imidazolylmagnesium halide treated with acetyl chloride in a sealed tube at 55–60° for two hours yielded the μ -acetyl derivative. They suggest that an unstable acetate, readily hydrolyzed by water, is first formed and then rearranges on heating to the stable form.



Mingoia²⁷² finds that pyrazole, like its isomer, imidazole, reacts with ethylmagnesium bromide, liberating one equivalent of ethane and forming a new Grignard reagent. Some of the reactions of pyrazolylmagnesium bromide reported by Mingoia are as follows:

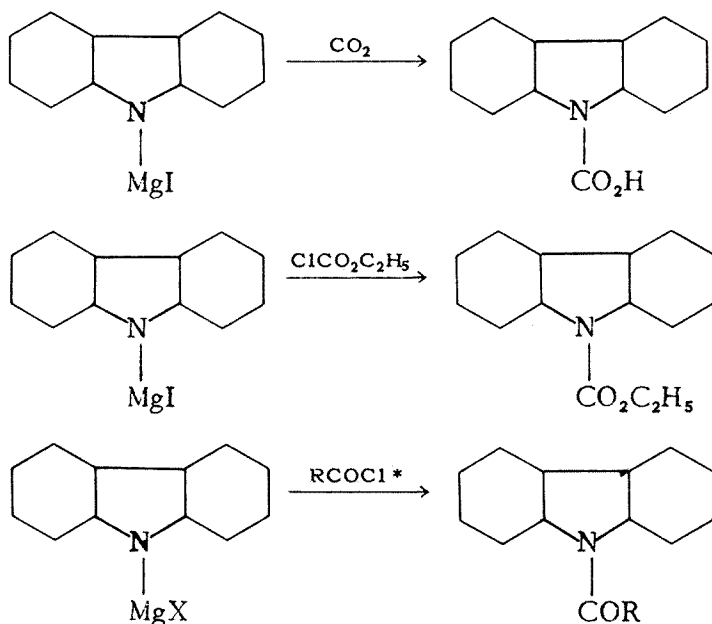


²⁷¹Oddo and Ingrassia, *Gazz. chim. ital.*, 61, 446–9 (1931); *Chem. Abstr.*, 26, 452 (1932).

²⁷²Mingoia, *Gazz. chim. ital.*, 61, 449–58 (1931); *Chem. Abstr.*, 26, 453 (1932).

When an ethereal solution of the Grignard reagent was treated with acetyl chloride, or acetic anhydride, pyrazole was recovered almost quantitatively. In a sealed-tube reaction at 60° for four hours, acetyl chloride did yield a little of the *N*-acetyl derivative.

Carbazole behaves like a typical secondary amine in that it reacts with ordinary Grignard reagents such as methylmagnesium iodide and ethylmagnesium bromide, liberating one equivalent of gaseous hydrocarbon, and forming nitrogen-linked Grignard reagents, which in turn react with carbon dioxide, chloroformic ester and carboxylic acid chlorides to form the usual *N*-derivatives.²⁷³



Carbazolylmagnesium iodide is reported to react with carbon dioxide in the absence of solvent at $250\text{--}270^\circ$ to yield a carbon-linked carboxylic acid, probably the *ortho* (1) derivative,^{273a, b} but this is doubtless an example of a well-known type of thermal rearrangement.

GRIGNARD REAGENTS FROM FREE RADICALS

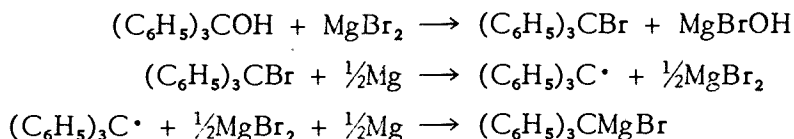
In the course of a discussion of the mechanism of Grignard reagent formation, Gilman and Fothergill²⁷⁴ announced, without supplying any details, that "it is possible to prepare triphenylmethylmagnesium iodide from triphenylmethyl and magnesium iodide ($\cdot\text{MgI}$)."

²⁷³ Oddo, (a) *Gazz. chim. ital.*, 41, I, 255-72 (1911); *Chem. Zentr.*, 1911, I, 1854; (b) *Mim. accad. Lincei*, [v], 14, 510-623 (1923); *Chem. Abstr.*, 19, 2492 (1925); (c) Sanna and Chessa, *Gazz. chim. ital.*, 58, 121-7 (1928); *Chem. Zentr.*, 1928, I, 2505; *Chem. Abstr.*, 22, 2562 (1928).

* $\text{R} = \text{CH}_3, \text{C}_2\text{H}_5, \text{C}_6\text{H}_5, \text{C}_2\text{H}_5\text{OCH}_2$.

²⁷⁴ Gilman and Fothergill, *J. Am. Chem. Soc.*, 51, 3149-57 (1929).

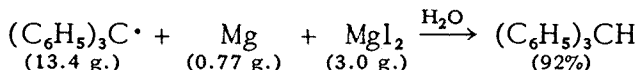
In the meantime, while investigating the possibility of the reduction of triphenylmethanol to triphenylmethyl by means of magnesium bromide and metallic magnesium, Gomberg and Bachmann²⁷⁵ found that, although the proposed interaction does produce triphenylmethyl (in addition to triphenylmethane), it is not in fact a simple reduction. In the course of their elucidation of the mechanism of the reaction, they found that when two equivalents of triphenylmethyl in 2:1 benzene-ethyl ether solution are heated for several hours on a steam-bath with one equivalent of magnesium bromide and a slight excess over one equivalent of metallic magnesium, triphenylmethylmagnesium bromide is produced in *ca.* 93 percent yield. They further noted that when triphenylmethyl bromide in 2:1 benzene-ethyl ether solution is treated with metallic magnesium, no Grignard reagent is detectable until more than half the magnesium present has reacted, although an ultimate yield of 96-97 percent is obtained. The series of reactions proposed to account for the phenomena observed is as follows:



Magnesium iodide may be substituted for magnesium bromide with similar results.

Bachmann²⁷⁶ reports that phenyl-*o*-biphenylenemethyl behaves similarly to triphenylmethyl when treated with magnesium bromide (or iodide) and metallic magnesium, although the reaction is slower.

In an extension of the earlier studies, Bachmann²⁷⁷ showed that only a small amount of magnesium iodide is necessary to bring about reaction between magnesium and triphenylmethyl, and suggests that the product is probably an equilibrium mixture of bistrisphenylmethylmagnesium, trisphenylmethylmagnesium iodide, and magnesium iodide.



ADDITION OF GRIGNARD REAGENTS TO OLEFINS

Blaise²⁷⁸ investigated qualitatively the possibility of the formation of addition compounds through the reaction of Grignard reagents with unsaturated hydrocarbons ("hexylene," "caprylene," phenylacetylene) with negative results. Since then various attempts to account for the formation of certain products of the reactions of Grignard reagents with un-

²⁷⁵ Gomberg and Bachmann, *J. Am. Chem. Soc.*, 52, 2455-61 (1930).

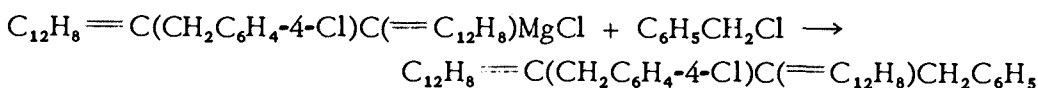
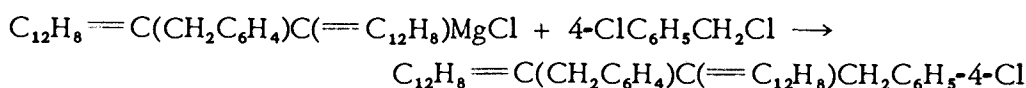
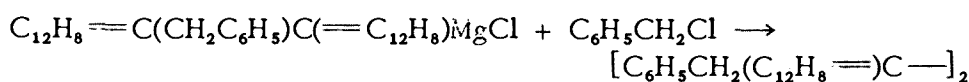
²⁷⁶ Bachmann, *J. Am. Chem. Soc.*, 52, 3287-90 (1930).

²⁷⁷ Bachmann, *J. Am. Chem. Soc.*, 52, 4412-3 (1930).

²⁷⁸ Blaise, *Compt. rend.*, 132, 38-41 (1901); *J. Chem. Soc.*, 80, I, 133 (1901).

saturated compounds²⁷⁹ by the assumption of Grignard reagent addition at a carbon-to-carbon double bond have been rather thoroughly discredited by Gilman and co-workers,²⁸⁰ who have also attempted the condensation of Grignard reagents with some thirty or more unsaturated hydrocarbons (olefinic, conjugated diolefinic, allenic, and acetylenic) without success. Other similar experiments with negative results have been reported by Wieland and Krause²⁸¹ and by Kinney and Larsen.²⁸²

More recently, however, Fuson,²⁸³ noting the reported reactivity of di-*o*-biphenyleneethylene (9,9'-bifluorenylidene) toward various carbonyl co-reactants,²⁸⁴ and its ability to condense with phenyllithium to form 1-phenyl-1,2-di-*o*-biphenyleneethane,²⁸⁵ recognized the possibility that condensation of this highly-conjugated olefin with a Grignard reagent might be effected, and reasoned that the chances of success would probably be greatest with one of the more reactive²⁸⁶ Grignard reagents. Condensation with *t*-butylmagnesium chloride (68 percent yield) was effected by eighteen hours reflux in benzene-ether solution. Similar condensations with benzylmagnesium chloride (57.6 percent yield) and *p*-chlorobenzylmagnesium chloride (12.5 percent yield) were brought about by reflux (*ca.* sixteen hours) in ether solution. The benzyl addition products were shown to be Grignard reagents by their further reaction with benzyl chlorides.



²⁷⁹ Staudinger, *Ann.*, 356, 51-123 (1907); Rupe and Burgin, *Ber.*, 43, 423-9 (1926); Rupe, *Ann.*, 402, 149-86 (1913); Lespieau, *Bull. soc. chim.*, [4], 29, 528-35 (1921); Staudinger, Kreis, and Shilt, *Helv. Chim. Acta*, 5, 743-56 (1922).

²⁸⁰ Gilman and Heckert, *J. Am. Chem. Soc.*, 42, 1010-4 (1920); Gilman and Crawford, *ibid.*, 45, 554-8 (1923); Gilman and Shumaker, *ibid.*, 47, 514-5 (1925); Gilman and Petersen, *ibid.*, 48, 423-9 (1926); Gilman and Harris, *ibid.*, 49, 1825-8 (1927); Gilman, Kirby, Fothergill, and Harris, *Proc. Iowa Acad. Sci.*, 54, 221-2 (1928); *Chem. Abstr.*, 22, 4504 (1928); Gilman and McGlumphey, *Rec. trav. chim.*, 47, 418-22 (1928); Gilman and Harris, *ibid.*, 49, 762-5 (1930); Gilman and Schulz, *J. Am. Chem. Soc.*, 52, 3588-90 (1930); Gilman and Kirby, *ibid.*, 54, 345-55 (1932).

²⁸¹ Wieland and Krause, *Ann.*, 443, 129-41 (1925).

²⁸² Kinney and Larsen, *J. Am. Chem. Soc.*, 57, 1054-6 (1935).

²⁸³ Fuson and Porter, *J. Am. Chem. Soc.*, 70, 895-7 (1948).

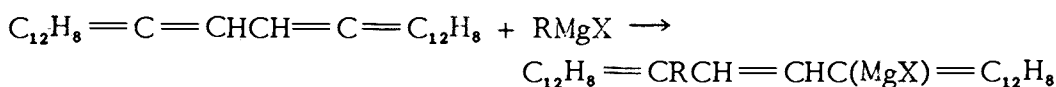
²⁸⁴ Pinck and Hilbert, *J. Am. Chem. Soc.*, 57, 2398-402 (1935); 68, 2014-6 (1946).

²⁸⁵ Ziegler and Schäfer, *Ann.*, 511, 101-9 (1934).

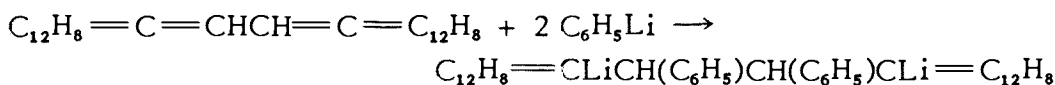
²⁸⁶ As regards carbonyl double-bond addition; see, *e.g.*, Kharasch and Weinhouse, *J. Org. Chem.*, 1, 209-30 (1936).

Attempted condensations of the olefin with methylmagnesium iodide and phenylmagnesium bromide were unsuccessful.

Extension of this study by Fuson *et al.*²⁸⁷ has shown that *t*-butylmagnesium, benzylmagnesium, and *p*-chlorobenzylmagnesium chlorides undergo 1,4-addition to 1,4-di-*o*-biphenylene-1,3-butadiene.

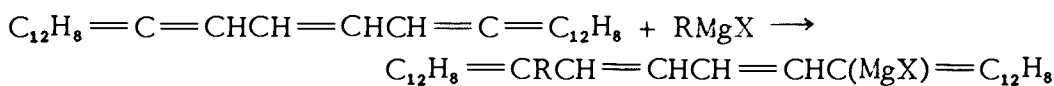


It is of incidental interest that, in contrast to the reactive Grignard reagents, phenyllithium appears to undergo a double 1,2-addition.

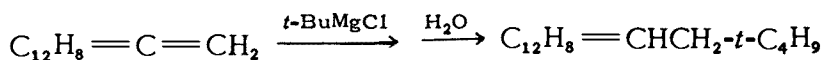


s-Butylmagnesium, phenylmagnesium, and phenethylmagnesium bromides did not react with this hydrocarbon under the conditions employed.

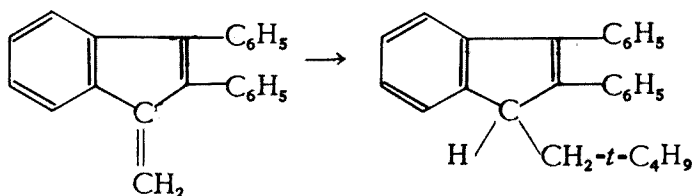
With the vinylog, 1,6-di-*o*-biphenylene-1,3,5-hexatriene, *t*-butylmagnesium and benzylmagnesium chlorides condensed additively in a 1,6 manner.



Although Wieland and Krause (*loc. cit.*²⁸¹) had reported negative results for methylmagnesium iodide and phenylmagnesium bromide, Fuson and Mumford²⁸⁸ found that *t*-butylmagnesium chloride reacts additively with dibenzofulvene (9-methylenefluorene), yielding, upon subsequent hydrolysis, 9-neopentylfluorene.



They also found that 2,3-diphenylbenzofulvene undergoes an analogous reaction to yield 1-neopentyl-2,3-diphenylindene.



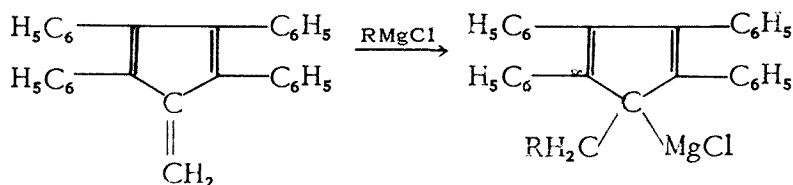
According to Fuson and York,²⁸⁹ 1,2,3,4-tetraphenylfulvene reacts with

²⁸⁷ Fuson, Dewald, and Gaertner, *J. Org. Chem.*, 16, 21-32 (1951).

²⁸⁸ Fuson and Mumford, *J. Org. Chem.*, 17, 255-61 (1952).

²⁸⁹ Fuson and York, *J. Org. Chem.*, 18, 570-4 (1953).

t-butylmagnesium and benzylmagnesium chlorides to form adducts of the type illustrated in the following equation.



GRIGNARD REAGENTS FROM ORGANOLITHIUM COMPOUNDS

Gilman²⁹⁰ calls attention to the fact that the prompt conversion of organolithium compounds to the corresponding Grignard reagents by means of magnesium bromide or iodide may be of preparative value for the synthesis of Grignard reagents otherwise obtained with difficulty. He cites by way of example *p*-dimethylaminophenylmagnesium bromide which is prepared from the bromide and magnesium with difficulty and in poor yields. The corresponding lithium compound, obtainable in 96 percent yield is said to be readily convertible to the Grignard reagent by treatment with magnesium iodide.

GRIGNARD REAGENTS FROM ORGANOMERCURI COMPOUNDS

Nesmeyanov and Pecherskaya²⁹¹ report that when *o*-chloromercuriphenol (5.0 g.) is treated with ethylmagnesium bromide (4.0 g.) it forms a Grignard reagent which, upon further treatment with benzophenone (2.8 g.), forms *o*-hydroxytriphenylmethanol in 25 percent yield. Ninety percent of the theoretical quantity of ethylmercuric chloride was recovered. Treatment of a similarly prepared Grignard reagent with carbon dioxide yielded salicylic acid (20 percent).

The same investigators²⁹² had previously reviewed the work of Abelmänn²⁹³ and of Grignard and Abelmänn²⁹⁴ on the reaction of α -chloromercuriacetophenone with ethylmagnesium bromide and had announced that the true product of the reaction is an enolate of acetophenone $[\text{C}_6\text{H}_5\text{C}(\text{OMgBr})=\text{CH}_2]$ which reacts with carbon dioxide to form the bromomagnesium salt of benzoylacetic acid ($\text{C}_6\text{H}_5\text{COCH}_2\text{CO}_2\text{MgBr}$).

GRIGNARD REAGENTS FROM ALKYL SULFATES

Suter and Gerhart²⁹⁵ report that ethyl sulfate reacts readily with magnesium in dry ethyl ether solution to give a slightly soluble Grignard-

²⁹⁰ Gilman and Swiss, *J. Am. Chem. Soc.*, 62, 1847-9 (1940).

²⁹¹ Nesmeyanov and Pecherskaya, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1943, 317-8; *Chem. Abstr.*, 38, 5492 (1944).

²⁹² Nesmeyanov and Pecherskaya, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1941, 67-74; *Chem. Zentr.*, 1942, I, 2389; *Chem. Abstr.*, 37, 3416 (1943).

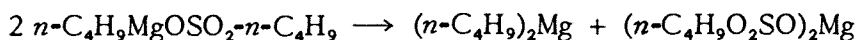
²⁹³ Abelmänn, *Ber.*, 47, 2931-5 (1914).

²⁹⁴ Grignard and Abelmänn, *Bull. soc. chim.*, [4], 19, 18-25 (1916).

²⁹⁵ Suter and Gerhart, *J. Am. Chem. Soc.*, 55, 3496 (1933).

type reagent that is said to give a "good" yield of ethylphenylcarbinol on treatment with benzaldehyde. *n*-Butyl sulfate reacts similarly with magnesium, and the product yields butane upon hydrolysis.

They also report²⁹⁶ that *n*-butylmagnesium bromide reacts with *n*-butylmagnesium sulfate to form *n*-butyl bromide and a Grignard-type reagent which was at first formulated as $n\text{-C}_4\text{H}_9\text{MgOSO}_2\text{-}n\text{-C}_4\text{H}_9$. Further study has shown, however, that only a small percentage of the basic magnesium is present in the precipitate formed in the reaction. If any large amount of *n*-butylmagnesium *n*-butyl sulfate is formed in the reaction it must disproportionate in the sense:



Optimum conditions for the preparation of di-*n*-butylmagnesium from magnesium and *n*-butyl sulfate are described as follows. "A mixture of 1.26 g. of magnesium (0.05 mole plus 5 percent excess) and 1.27 g. (0.01 g.-atom) of iodine was covered with 60 ml. of ether in a graduated flask and warmed slightly until the iodine was converted into magnesium iodide. To the mixture was added, over a period of three hours, 10.5 g. (0.05 mole) of *n*-butyl sulfate, and refluxing [was] continued for an additional hour. Titration of the filtered reaction mixture indicated a 78-80 percent yield of di-*n*-butylmagnesium."

Use of the same procedure with methyl sulfate gave only a 28 percent yield of dimethylmagnesium, probably because of reaction of the dimethylmagnesium formed with excess ester (see Alkyl Sulfates, Chapter XXI). The gas evolved was a mixture of ethane (96.1 percent) and methane, the amount of ethane corresponding to approximately 50 percent of the theoretical.

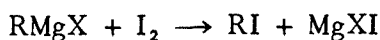
²⁹⁶ Suter and Gerhart, *J. Am. Chem. Soc.*, 57, 107-9 (1935).

CHAPTER III

Estimation and Detection of Grignard Reagents

ESTIMATION

Boudroux¹ reported that the addition of powdered iodine to ethereal solutions of organomagnesium bromides or chlorides gives yields of the order of 80 percent of the corresponding organic iodides, according to the equation:

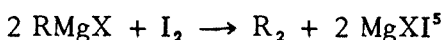


Notwithstanding the fact that Boudroux's report scarcely indicated a quantitative reaction, Jolibois² adopted it as the basis for a method of Grignard reagent evaluation which consisted essentially in titrating an aliquot portion of the reagent with a standard solution of iodine, the persistence of iodine color being accepted as an indication of the completion of the titration.

This method was also used by Leroide³ for the evaluation of *n*-propylmagnesium chloride and bromide solutions.

The iodine-Grignard reagent reaction was investigated in somewhat more detail by Datta and Mitter⁴, who found that the conditions of reaction have a marked influence on the products and yields obtained. They reported, in part, that when solid iodine is added gradually to an ethereal solution of phenylmagnesium bromide, there are obtained iodobenzene in 25 to 30 percent yield and benzene in 30 to 40 percent yield, together with a small quantity of biphenyl, but that, when phenylmagnesium bromide solution is added to ethereal iodine solution, iodobenzene is formed in 90 percent yield. They also found that ethylmagnesium iodide, when treated with iodine, gives only a small yield of ethyl iodide.

In view of the byproducts reported for phenylmagnesium bromide, it is obvious that side-reaction is not adequately described by the equation:



When the collateral evidence is taken into account, it appears possible

¹Boudroux, *Compt. rend.*, 135, 1350-1 (1902); *J. Chem. Soc.*, 84, I, 221 (1903).

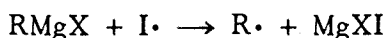
²Jolibois, *Compt. rend.*, 155, 213-5 (1912); *Chem. Abstr.*, 6, 2740 (1912).

³Leroide, *Ann. chim.*, [9], 16, 354-410 (1921).

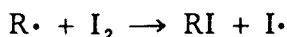
⁴Datta and Mitter, *J. Am. Chem. Soc.*, 41, 287-92 (1919).

⁵See: Gilman, Wilkinson, Fishel, and Meyers, *J. Am. Chem. Soc.*, 45, 150-8 (1923).

that reaction leading to both the desired product and the byproducts is initiated by some such process as:



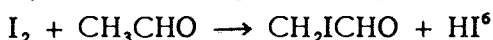
In the presence of an excess of iodine, the reaction might then be expected to proceed predominantly as follows:



whereas, in the absence or scarcity of iodine, the free radicals liberated might be expected to attack the solvent or the Grignard reagent, or to dimerize, or to disproportionate in accordance with their respective natures (see Mechanism and Kinetics of Grignard Reagent Formation, Chapter II).

It would be difficult to account for the relatively high yield of benzene reported on any basis other than the attack of free phenyl radicals upon the solvent (assuming that reasonable precautions against moisture were taken, and that the persistence of iodine coloration does in fact indicate total consumption of the Grignard reagent*). Biphenyl (aside from that formed in the preparation of the Grignard reagent) might be due in part to reaction of phenyl radicals with the Grignard reagent and in part to attack of phenyl radicals on benzene.

Whatever the exact nature of the desired and side-reactions, the stoichiometrical fact remains that the latter require only half as much iodine per mole of Grignard reagent as the former. To the extent that the liberated free radicals attacked the solvent (ethyl ether), however, the error might be compensated, at least in part, for acetaldehyde (a postulated product) reacts readily with iodine, presumably according to the equation:



Gilman *et al.* (*loc. cit.*⁵) have reviewed the possibilities of Grignard reagent determination and have discarded the iodimetric method on the ground that the reaction upon which it is based is not quantitative.

Their attempts to find a quantitative co-reactant that would yield a product that could be determined gravimetrically were unsuccessful. Phenyl isocyanate proved unsatisfactory and other compounds (not specified) even more so.

They investigated an "indirect" method of analysis which involved evaluation of the amount of magnesium consumed in Grignard reagent formation and in side-reactions by determination of loss in weight, and evaluation of the amount of organic halide consumed by Volhard determination of halide ion produced. Although the results were fairly consistent with those of the gas analysis method which they adopted as standard, they felt that the method, which necessitated filtration, either

*Total consumption of the reagent was assumed, but not demonstrated, in the study cited.

⁶Chautard, *Ann. chim.*, [6], 16, 145-200 (1889).

admitted of too great errors by reason of moisture and oxygen contamination, or demanded too exacting a technique for convenience and rapidity.

The gas analysis method, considered standard, was an adaptation of the Zerewitinoff⁷ method for the determination of active hydrogen. It consisted of measuring the amount of gas evolved when a Grignard reagent is hydrolyzed. Obviously this method is restricted in scope to Grignard reagents yielding, upon hydrolysis, hydrocarbons that are gases at ordinary temperatures.

The acid titration method finally adopted is based upon the fact that hydrolysis of the active constituents of the Grignard reagent (R_2Mg , $RMgX$) produces "basic magnesium" $Mg(OH)_2$, $MgXOH$, whereas the inert magnesium halide is unaffected. The principle potential sources of error are the production of "basic magnesium" by the direct attack of water on magnesium, or by the destruction of a portion of the Grignard reagent by moisture, and the production of $(RO)_2Mg$ and $ROMgX$ by atmospheric oxygen. Carbon dioxide would give products yielding equivalent quantities of acid and base upon hydrolysis, as Gilman *et al.* suggest, only if reaction stopped at the RCO_2MgX stage, which seems highly improbable in the presence of a huge excess of Grignard reagent. Nevertheless, the standard precautions in preparation and handling would minimize such errors.

The procedure followed was to add 50 ml. of distilled water to a 20-ml. aliquot portion of Grignard reagent solution and then to add an estimated 20 ml. excess of standard acid (H_2SO_4 , *ca.* 0.25 N). Back-titration was effected with standard sodium hydroxide solution with the aid of methyl orange as indicator.

Results obtained by this method ran uniformly about 4 percent higher than those obtained by the gas analysis method.

Job *et al.*⁸ have objected to the acceptance of the gas analysis method as a standard of reference, and have maintained that, when proper technique is used, the iodimetric method is the most accurate available. Their criticism of the gas analysis method is based principally upon the claim that the gas evolved upon hydrolysis of ethylmagnesium bromide always contains a considerable proportion of ethylene.

The procedure advocated by Job and Reich employs an estimated two-fold excess of a solution of *ca.* 50 g. per l. of dry iodine in anhydrous ether. To this is added a 1- to 2-ml. sample of the Grignard solution and then 200-300 ml. of aqueous acetic acid solution. The excess of iodine is titrated with 0.1 N sodium thiosulfate solution. It is unnecessary that the iodine solution be standardized if an iodine blank is titrated with each sample.

⁷Zerewitinoff, *Ber.*, 40, 2023-31 (1907).

⁸Job and Reich, *Bull. soc. chim.*, [4], 33, 1414-33 (1923); Job, Reich, and Dubien, *ibid.*, [4], 37, 976-7 (1925).

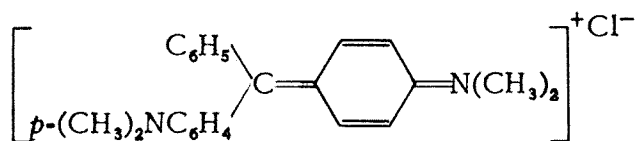
Gilman and Meyers⁹ undertook a comparison of the gas-analysis and acid-titration methods with the modified iodimetric method of Job and Reich. They reported inability to duplicate the results of Job and Reich as regards the degree of discrepancy between the gas analysis and acid titration methods on the one hand and the iodimetric method on the other. Their report indicated that, on the average, acid titration gives results about 5 percent higher than gas analysis, whereas iodine titration gives results about 10 percent lower.

In a subsequent report, Gilman *et al.*,¹⁰ recommend that the acid-Grignard mixture be heated for about fifteen minutes before back-titration. Phenolphthalein is also preferred to methyl orange as indicator, not only because it gives a more readily recognizable end-point, but because it gives somewhat lower results, thus bringing the acidimetric determinations within about 1 percent of the gas-analysis determination.

Whatever the merits of the iodimetric-acidimetric controversy, organic chemists appear to have accepted the acidimetric method rather generally, possibly because of the extreme simplicity of its technique and the consistency of its results. Incidentally, smaller aliquot portions of Grignard solution and lower concentrations of standard acid and base than those originally employed by Gilman *et al.* have been found entirely satisfactory.

DETECTION

As early as 1904, Sachs and Sachs¹¹ suggested that Michler's ketone, $[p-(\text{CH}_3)_2\text{NC}_6\text{H}_4]_2\text{CO}$, should constitute an ideal test reagent for phenylmagnesium bromide because of the facility with which these compounds interact to form Malachite green,



For more than two decades, however, no successful attempt was made to discover a general detector for Grignard reagents. Gilman and Schulze¹² then announced that Michler's ketone itself could serve as such a detector.

They describe the test procedure as follows: "One-half to 1 ml. of the solution to be tested is treated, at room temperature, with an equal volume of a 1 percent solution of Michler's ketone in dry benzene. The reaction product is then hydrolyzed by the slow addition of 1 ml. of water, during which the test-tube is gently agitated to moderate the vigor of the reaction. The subsequent addition of several drops of a 0.2 per-

⁹Gilman and Meyers, *Rec. trav. chim.*, 45, 314-9 (1926).

¹⁰Gilman, Zoellner, and Dickey, *J. Am. Chem. Soc.*, 51, 1576-83 (1929).

¹¹Sachs and Sachs, *Ber.*, 37, 3088-92 (1904).

¹²Gilman and Schulze, *J. Am. Chem. Soc.*, 47, 2002-5 (1925).

cent solution of iodine in glacial acetic acid develops a characteristic greenish-blue color when Grignard reagent is present."

Some twenty-five Grignard reagents were tested, and of these, only one ($\text{C}_6\text{H}_5\text{C}\equiv\text{CMgBr}$) gave a comparatively weak, though still positive test. In general only the true Grignard reagents, in which magnesium is attached directly to carbon, give positive tests. Grignard-type reagents containing the groupings $-\text{OMgX}$, $-\text{NMgX}$, $-\text{SMgX}$ or $-\text{AsMgX}$ are negative. Some enolates, notably that of acetomesitylene, which gives a positive test, may, however, be exceptions.¹³ In general, organometallic compounds other than Grignard reagents which can add to the carbonyl group ($\text{C}_6\text{H}_5\text{CaI}$, $\text{C}_6\text{H}_5\text{BaI}$, $\text{C}_2\text{H}_5\text{Na}$, $4\text{-CH}_3\text{C}_6\text{H}_4\text{Na}$) gave positive tests, whereas those incapable of reacting additively with the carbonyl group $\text{C}_2\text{H}_5\text{ZnI}$, $(\text{C}_2\text{H}_5)_2\text{Zn}$, $(\text{C}_2\text{H}_5)_2\text{Hg}$, $(4\text{-CH}_3\text{C}_6\text{H}_4)_2\text{Hg}$, $4\text{-CH}_3\text{C}_6\text{H}_4\text{HgI}$, $(\text{C}_2\text{H}_5)_4\text{Pb}$ gave negative tests. Benzene, dimethylaniline, pyridine, and quinoline do not interfere. Gilman and Heck¹⁴ later found that pyrrole, acetic acid, and iodine give a blue coloration that might be mistaken for a positive test.

The sensitivity of the test was investigated with ethylmagnesium bromide, which was found to be detectable at a concentration of 0.037 M.

One limitation of the test should be noted: it cannot always be relied upon to indicate the complete utilization of a Grignard reagent in a reaction, particularly in a reaction with a relatively reactive co-reactant. In a study of the relative reactivities of aldehydes and ketones, Kharasch and Cooper¹⁵ found that Michler's ketone sometimes gave a negative test when the presence of large quantities of Grignard reagent could be demonstrated by treating the solution with ethereal mercuric chloride and subsequently isolating the organomercuric chloride corresponding to the Grignard reagent.

To investigate the sensitivity of the color test in the presence of a compound that condenses relatively rapidly with the Grignard reagent, the following procedure was adopted.¹⁵ To each of a series of test-tubes was added 0.5 ml. of a 1 percent solution of Michler's ketone in dry benzene and a measured amount of a 1 percent solution of pure benzaldehyde in dry benzene; 0.5 ml. of ethereal phenylmagnesium bromide solution (*ca.* 1.5 N) was then added. The contents were then treated with 1 ml. of water and, finally with five drops of a 0.2 percent solution of iodine in glacial acetic acid. The appearance of a greenish coloration was considered a positive test. The results are summarized in Table III-I.¹⁵ The color test would probably prove sensitive in the presence of relatively high concentrations of Grignard co-reactants less reactive than Michler's ketone, or of about the same degree of reactivity. However,

¹³Gilman and Jones, *J. Am. Chem. Soc.*, 63, 1162-3 (1941).

¹⁴Gilman and Heck, *J. Am. Chem. Soc.*, 52, 4949-54 (1930).

¹⁵Cooper, Doctoral dissertation, University of Chicago, 1937; Kharasch and Cooper, *J. Org. Chem.*, 10, 46-54 (1945).

*Apparently, the order of reactivity implied here is that toward benzonitrile [See: Gilman, St. John, St. John, and Lichtenwalter, *Rec. trav. chim.*, 55, 577-85 (1936); Gilman, "Organic Chemistry," John Wiley & Sons, Inc., New York, 2nd ed., 1943, Vol. I, pp. 518-9].

It may be applied by adding 1.0 ml. of the organometallic solution to 1.0 ml. of an approximately 1.0 percent solution of triphenylbismuth dichloride in dry benzene. With aryllithium and most arylmagnesium compounds a deep purple color appears instantaneously. This test was found to be positive for diphenylmagnesium and for phenyl-, *o*-tolyl-, *p*-tolyl-, α -naphthyl-, and *p*-chlorobenzylmagnesium bromides; it is negative for ethyl-, *n*-propyl-, *n*-butyl-, and mesitylmagnesium bromides. The nature of the colored compounds formed in positive tests is not certainly known.

CHAPTER IV

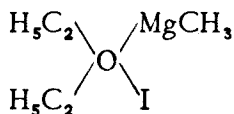
Constitution and Dissociation of Grignard Reagents

SOLVENT ASSOCIATION

The constitution of the Grignard reagent, particularly in ethereal solution, has been the subject of a great deal of experimental study, and of speculation and controversy *ad libitum*. Early contributions in the field have been reviewed by (*inter alios*): Thorp and Kamm,¹ Grignard,² Meisenheimer and Casper,³ Terentjew,⁴ Courtot,⁵ Gilman and Fothergill,⁶ Runge⁷ and Jolibois and Kullmann.^{7,1} Because much of the material involved can now be of little more than antiquarian interest, a brief historical resumé rather than an exhaustive review is here presented.

The analyses of Grignard⁸ and of Blaise⁹ had shown that, when an ethereal solution of an organomagnesium halide (CH_3MgI , $\text{C}_2\text{H}_5\text{MgBr}$, $\text{C}_2\text{H}_5\text{MgI}$) is evaporated, and the residue is dried under reduced pressure, one molecule of ether per molecule of organomagnesium halide is retained with great tenacity, being removed only partially after several hours at temperatures as high as 150° . Grignard⁸ originally suggested that in such residues ether plays a rôle analogous to that of water of crystallization.

In a discussion of oxonium compounds and the potential quadrivalency of oxygen, Baeyer and Villiger¹⁰ cited these data, and proposed for methylmagnesium iodide from ethyl ethereal solution the formulation



¹Thorp and Kamm, *J. Am. Chem. Soc.*, 36, 1022-8 (1914).

²Grignard, (a) *Bull. soc. chim.*, [4], 13, Conference I-XXXVIII (1913); (b) [4], 39, 1285-321 (1926).

³Meisenheimer and Casper, *Ber.*, 54B, 1655-65 (1921).

⁴Terentjew, *Z. anorg. Chem.*, 156, 73-84 (1926).

⁵Courtot, "Le Magnesium en Chimie Organique," Nancy, 1926, pp. 32-44.

⁶Gilman and Fothergill, *J. Am. Chem. Soc.*, 51, 3149-57 (1929).

⁷Runge, "Organometalverbindungen. I Teil: Organomagnesiumverbindungen," Stuttgart, 1932, pp. 5-7.

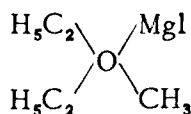
^{7,1}Jolibois and Kullmann, *Bull. soc. chim.*, [5], 17, 919-32 (1950).

⁸Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).

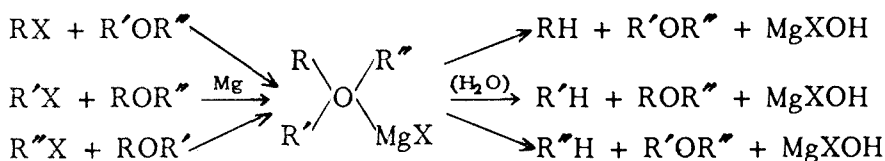
⁹Blaise, *Compt. rend.*, 132, 839-41 (1901); *Chem. Zentr.*, 1901, I, 1000.

¹⁰Baeyer and Villiger, *Ber.*, 35, 1201-12 (1902).

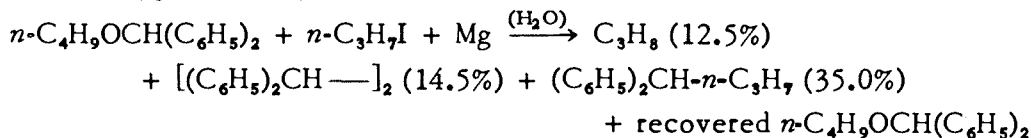
Grignard¹¹ accepted in principle the concept of an ethereal organo-magnesium halide as an oxonium compound, but preferred, as more consistent with the mode of scission of such compounds in chemical reactions, the formulation



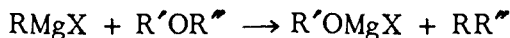
It would be a necessary implication of Grignard's hypothesis that the unsymmetrical etherate of a Grignard reagent with an organic radical foreign to the ether be preparable in three different ways, and that, of the three conceivable modes of subsequent reaction of the etherate, the preferred one might or might not yield a non-ethereal product corresponding to the alkyl halide employed in the preparation of the Grignard reagent



Stadnikoff,¹² working for the most part with readily-cleaved ethers,* such as ethyl triphenylmethyl, propyl benzhydryl, and butyl benzhydryl, supposed that he had accumulated evidence in favor of the oxonium intermediate hypothesis by effecting such reactions as:



Gorskii¹³ and Tschellinzeff¹⁴ correctly characterized these reactions as involving ether cleavages of the type:



Thorpe and Kamm¹⁵ demonstrated conclusively that the etherates derived from ethyl ether, bromobenzene, and magnesium, on the one hand, and phenetole, ethyl bromide, and magnesium, on the other, are not identical.

¹¹Grignard, *Compt. rend.*, 136, 1260-2 (1903); *J. Chem. Soc.*, 84,1, 552 (1903); *Bull. soc. chim.*, [3], 29, 944-8 (1903).

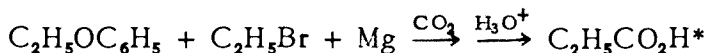
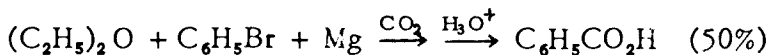
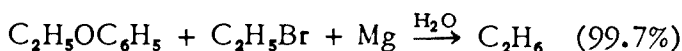
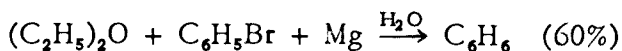
¹²Stadnikoff, *J. Russ. Phys.-Chem. Soc.*, 43, 1244-57 (1911); 44, 1219-47, 1256-64 (1912); *Chem. Abstr.*, 6, 1434 (1912); 7, 983, 984 (1913); *Ber.*, 44, 1157-60 (1911); 46, 2496-503 (1913); *J. prakt. Chem.*, [2], 88, 1-20 (1913).

*See: Chapter XV, Reactions of Grignard Reagents with Ethers, Acetals, and Ketals.

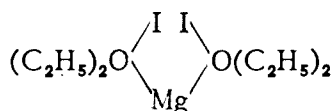
¹³Gorskii *J. Russ. Phys.-Chem. Soc.*, 44, 581-6 (1912); 45, 163-6 (1913); *J. Chem. Soc.*, 102,1, 622 (1912); 104,1, 462 (1913).

¹⁴Tschellinzeff and Pavloff, *J. Russ. Phys.-Chem. Soc.*, 45, 289-300 (1913); *J. Chem. Soc.*, 104,1, 461 (1913).

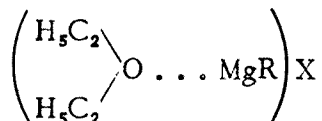
¹⁵Thorpe and Kamm, *J. Am. Chem. Soc.*, 36, 1022-8 (1914).



Zelinsky¹⁶ prepared a "dietherate" of magnesium iodide and "trietherates" of magnesium bromide and magnesium iodide, from which two molecules of ether could be rather readily removed to produce the more stable "monoetherate." Blaise¹⁷ isolated a crystalline compound, resulting from the reaction of ethereal iodine with magnesium, which he believed to be the "dietherate" of magnesium iodide, and for which he proposed the formulation



Tschelinzeff¹⁸ prepared organomagnesium halides ($\text{C}_2\text{H}_5\text{MgI}$, $n\text{-C}_3\text{H}_7\text{MgI}$, $i\text{-C}_4\text{H}_9\text{MgI}$, $i\text{-C}_5\text{H}_{11}\text{MgI}$) in benzene and benzine solutions with the aid of a few drops of dimethylaniline "catalyst," and measured the heat evolved upon the addition of an equivalent of ethyl ether. On the ground that the heat effect does not vary much for the Grignard reagents or the solvents investigated, he preferred to regard the "monoetherates" as Werner¹⁹ complexes rather than as oxonium salts, and he suggested the formulation



In a continuation of this study, Tschelinzeff²⁰ isolated and analyzed the "dietherates" of isopropyl- and isoamylmagnesium iodides, and determined that the thermal increments for addition of the first and second equivalents of ether were approximately equal. For the "dietherates"

*Propionic acid was not specifically identified as such, but it was shown that the readily-distillable acid obtained included no traces of either benzoic or halogen acids.

¹⁶Zelinsky, *J. Russ. Phys.-Chem.*, 35, 399-404 (1903); *J. Chem. Soc.*, 84, I, 802.

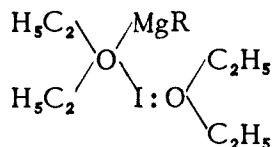
¹⁷Blaise, *Compt. rend.*, 139, 1211-3 (1904); *J. Chem. Soc.*, 88, I, 111 (1905).

¹⁸Tschelinzeff, *Ber.*, 37, 2081-92, 4534-40 (1904); 38, 3664-73 (1905); 39, 773-9 (1906).

¹⁹Cf. Werner, *Ann.*, 322, 261-351 (1902).

²⁰Tschelinzeff, *Ber.*, 39, 773-9 (1906).

he employed the formulation

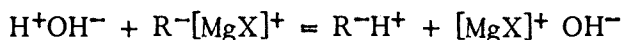


Investigating the heats of hydrolysis of several "isomeric" ether-Grignard reagent complexes ($\text{RMgX} \cdot 2 \text{R}'\text{OR}''$), Tschelinzeff²¹ found the differences to be of the order of the experimental error—a fact which he regarded as constituting a further argument in favor of a Werner complex formulation as opposed to an oxonium salt formulation.

Zerewitinoff²² reported that methylmagnesium iodide forms a crystalline monoetherate with amyl ether.

GRIGNARD REAGENT ASSOCIATION

In the meantime Abegg²³ made two suggestions to which chemists apparently paid little attention at the time, but which were subsequently repropounded, and which, in principle, are now universally accepted. He assigned a polar constitution to the Grignard reagent and described the hydrolysis reaction by the equation



He also mentioned the possibility of a disproportionation reaction in the sense



and (in a footnote) remarked: "Es wäre wichtig festzustellen, ob hier nicht ein Gleichgewicht erreicht werden kann."

Jolibois²⁴ reported that, whereas the diethylmagnesium of Lohr²⁵ is virtually insoluble in ethyl ether, it dissolves readily in an ethereal solution of magnesium iodide to give a solution which has various of the properties of an ethylmagnesium iodide solution prepared in the usual way. He further reported that under certain specified conditions such a solution may be electrolyzed with the deposition of magnesium at the cathode and without apparent gas evolution. On these grounds, he suggested that the Grignard reagent should be represented as $\text{Mg}(\text{C}_2\text{H}_5)_2 \cdot \text{MgI}_2$.

Grignard (*loc. cit.*²²) admitted that molecular-weight determinations on organomagnesium halides in ether solution seemed to indicate a molecule twice the size indicated by the simple formula RMgX , but pointed out that the same is true of magnesium iodide, and maintained that such

²¹Tschelinzeff, *Compt. rend.*, 144, 88-90 (1907); *Chem. Abstr.*, 1, 1122 (1907).

²²Zerewitinoff, *Ber.*, 41, 2244-5 (1908).

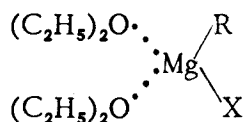
²³Abegg, *Ber.*, 38, 4112-6 (1905).

²⁴Jolibois, *Compt. rend.*, 155, 353-5 (1912); *Chem. Abstr.*, 6, 2741 (1912).

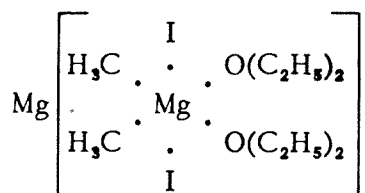
²⁵Lohr, *Ann.*, 261, 48-87 (1891).

determinations could in no wise distinguish between $R_2Mg \cdot MgX_2$ and $(RMgX)_2$.

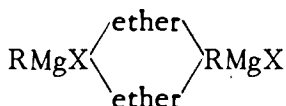
Meisenheimer and Casper²⁶ presented various arguments against the formulation of Grignard reagents as oxonium salts and proposed that the "dietherates," which they regarded as the usual components of Grignard solutions at ordinary temperatures, be formulated as complexes of the type



Terentjew (*loc. cit.*⁴) confirmed for methylmagnesium iodide in ethereal solution the "double" molecular weight observed by Grignard, and suggested the formulation $Mg[l_2 \cdot Mg \cdot (CH_3)_2 \cdot 2(C_2H_5)O]$, or, more specifically,



Job and Dubien²⁷ proposed the somewhat similar, though less specific formulation



Meisenheimer and Schlichenmaier²⁸ repeated and extended Terentjew's study of the molecular weight of methylmagnesium iodide in ethyl ether and reported that the apparent molecular weight varies with the concentration of the solution. They regarded their monomolecular formulation as satisfactory, and attributed higher apparent molecular weights to "molecular association."

Various chemical expedients were invoked for the purpose of effecting a choice between the "symmetrical" formulation of Jolibois ($R_2Mg \cdot MgX_2$) and the "unsymmetrical" formulation of Grignard ($RMgX$) or its bimolecular equivalent $[(RMgX)_2]$. All proved inconclusive, and, in the light of present knowledge, much of the discussion seems trivial. A few examples should serve as illustrative.

Job and Dubien²⁹ believed that measurement of the rate of gas evolution when a large excess of magnesium is treated with ethereal ethyl

²⁶Meisenheimer and Casper, *Ber.*, 54B, 1655-65 (1921).

²⁷Job and Dubien, *Compt. rend.*, 184, 155-7 (1927).

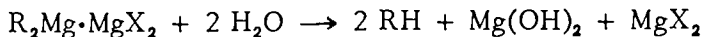
²⁸Meisenheimer and Schlichenmaier, *Ber.*, 61B, 720-9 (1928).

²⁹Job and Dubien, *Bull. soc. chim.*, [4], 39, 383 (1926).

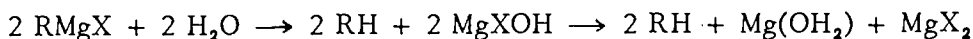
bromide at the boiling point of ether could establish a reaction order and hence permit a choice between RMgBr and $\text{R}_2\text{Mg} \cdot \text{MgBr}_2$.

Ivanoff³⁰ argued that magnesium bromide should be ether-extractable from $(\text{C}_2\text{H}_5\text{CO}_2)_2\text{Mg} \cdot \text{MgBr}_2$ but not from $\text{C}_2\text{H}_5\text{CO}_2\text{MgBr}$.

The question whether a Grignard reagent is hydrolyzed according to the equation:



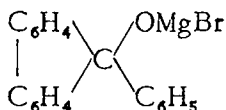
or according to the equation:



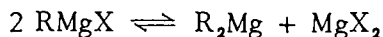
was debated by Kierzek³¹ and Mingoia³².

THE SCHLENK EQUILIBRIUM

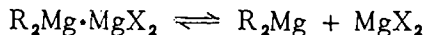
Schlenk and Schlenk³³ commented upon the futility of attempting to decide between the Grignard and Jolibois formulations on the basis of purely chemical evidence, and stated, though without presentation of experimental detail, that under the same conditions, "phenylmagnesium bromide" reacts with benzophenone to give $[(\text{C}_6\text{H}_5)_3\text{CO}]_2\text{Mg}$, but with fluorenone to give



They found, however, that virtually all the halogen and part of the magnesium may be precipitated from an ethereal Grignard reagent ($\text{C}_2\text{H}_5\text{MgI}$, $\text{C}_6\text{H}_5\text{MgBr}$) solution by the addition of dioxane. They interpreted this fact, in what still seems the only plausible manner, as indicating that the Grignard reagent exists in a state of equilibrium, which, reduced to its simplest terms, may be represented by:



or



The equilibrium point of the former equation should, they argued, be independent of concentration; that of the latter should vary with concentration. Schlenk and Schlenk found no change in the apparent equilibrium point upon eightfold dilution of a "concentrated" ethylmagnesium iodide solution with ether.

³⁰Ivanoff, *Compt. rend.*, 185, 505-7 (1927); cf. comment by Grignard, *ibid.*, 185, 507-9 (1927).

³¹Kierzek, *Bull. soc. chim.*, [4], 41, 759, 1299-1308 (1927); cf. comment by Grignard, *ibid.*, [4], 41, 759-60 (1927).

³²Mingoia, *Gazz. chim. ital.*, 58, 532-41 (1928).

³³Schlenk and Schlenk, *Ber.*, 62B, 920-4 (1929).

They also investigated the rate at which equilibrium is attained, and found it very rapid, if not instantaneous, in the case of phenylmagnesium bromide, but relatively slow in the case of ethylmagnesium iodide. Cope,³⁴ however, reports rapid attainment of equilibrium for ethylmagnesium iodide and ethylmagnesium bromide as well as phenylmagnesium bromide.

Upon the assumption that the true equilibrium point may be ascertained in the manner described, Schlenk³⁵ made the determinations recorded in the upper part of Table IV-I. Further determinations by Cope³⁶ are recorded in the lower part of Table IV-I. Additional values are reported by Noller and Hilmer,³⁷ by Johnson and Adkins³⁸ and by Bartlett and Barry.³⁹ That the values are reasonably reproducible is indicated by the concordant figures for phenylmagnesium bromide and iodide.

TABLE IV-I
DISPROPORTIONATION EQUILIBRIA (?) OF GRIGNARD REAGENTS
IN ETHYL ETHER SOLUTION

<u>RX</u>	<u>RMgX (%)</u>	<u>R₂Mg (%)</u>	<u>MgX₂ (%)</u>
CH ₃ I	87.0	6.5	6.5
C ₂ H ₅ I	43.0	28.5	28.5
C ₂ H ₅ Br	41.0	29.5	29.5
C ₂ H ₅ Cl	15.0	42.5	42.5
<i>n</i> -C ₃ H ₇ I	24.0	38.0	38.0
<i>n</i> -C ₃ H ₇ Br	24.0	38.0	38.0
<i>n</i> -C ₃ H ₇ Cl	17.0	41.5	41.5
C ₆ H ₅ I	38.0	31.0	31.0
C ₆ H ₅ Br	30.0	35.0	35.0
<hr/>			
C ₆ H ₅ I	39.0	30.5	30.5
C ₆ H ₅ Br	28.5	35.75	35.75
2,4-(CH ₃) ₂ C ₆ H ₃ Br	44.0	28.0	28.0
2,4-(CH ₃) ₂ C ₆ H ₃ I	55.0	22.5	22.5
2,4,6-(CH ₃) ₃ C ₆ H ₂ Br	64.0	18.0	18.0

Cope (*loc. cit.*³⁴) has found that the equilibrium point, as measured in this way, varies with temperature and with the solvent. For phenylmagnesium bromide 0.2178 *N* in magnesium, the percentage of (C₆H₅)₂Mg rises from 31.0 at -15° to 35.0 at 35°. At 20°, the percentage is 12.0 in *n*-butyl ether as compared to 33.5 in ethyl ether. For methylmagnesium iodide at 20°, the percentages are 0.1 in *n*-butyl ether and 1.0 in ben-

³⁴Cope, *J. Am. Chem. Soc.*, 57, 2238-40 (1933).

³⁵Schlenk, *Ber.*, 64B, 734-6 (1931).

³⁶Cope, *J. Am. Chem. Soc.*, 56, 1578-81 (1934).

³⁷Noller and Hilmer, *J. Am. Chem. Soc.*, 54, 2503-6 (1932).

³⁸Johnson and Adkins, *J. Am. Chem. Soc.*, 54, 1943-7 (1932).

³⁹Bartlett and Barry, *J. Am. Chem. Soc.*, 56, 2683-5 (1934).

zene, which may be compared to Schlenk's figure of 6.5 in ethyl ether at room temperature.

Cope⁴⁰ also showed that pyridine may be used as a precipitant, although it does not effect as complete halogen removal as does dioxane. The indicated $(C_6H_5)_2Mg$ percentages for phenylmagnesium bromide solutions under comparable conditions are 34.0–34.5 for pyridine and 30.0–32.0 for dioxane. Isoquinoline proved unsatisfactory as a precipitant.

Subsequent studies by Noller *et al.*⁴¹ have thrown doubt on the reliability of the dioxane-precipitation method as a means of establishing the actual state of equilibrium in a Grignard solution. Cope (*loc. cit.*³⁴) had already noted that the diphenylmagnesium content of an ethereal solution increases with time when the solution is allowed to stand in contact with the dioxane precipitate from the original phenylmagnesium bromide solution. Noller and White^{41 a} found that the same phenomenon occurred when solutions of ethyl-, isobutyl-, *t*-butyl- and phenylmagnesium bromides were subjected to dioxane precipitation, and the resultant mixtures were then shaken for several hours. Ethylmagnesium bromide was studied in greatest detail, and to some solutions were added excess magnesium bromide or diethylmagnesium in varying amounts. Under these conditions, naturally enough, satisfactory equilibrium data were not obtained, although the amount of ethyl radical remaining in the precipitate increased in a general way with the amount of bromine present. With shaking, all the precipitates tended to approach a constant composition, regardless of the composition of the original solution.

The question that arises, of course, is whether the increase in R_2Mg content of the ethereal solution on standing or shaking with the dioxane precipitate is due to leaching of occluded or coprecipitated R_2Mg or to gradual disproportionation of precipitated $RMgX$. Noller and White believe the change is too great to be accounted for by mere occlusion. In solutions dilute enough for the solute to be approximately monomolecular, coprecipitation should be negligible. The fact that Cope^{34,40} found that the ethereal solutions always contain detectable traces, though analytically insignificant quantities, of halogen makes it seem not too improbable that further disproportionation of the solid phase may take place on prolonged contact with the solution.

As a matter of practical interest, however, yields of diorganomagnesium compounds prepared by the method of Schlenk⁴² may be materially enhanced by shaking the dioxane precipitate with the solution for periods of four to ten hours (Noller and White, *loc. cit.*^{41 a}).

⁴⁰Cope, *J. Am. Chem. Soc.*, 60, 2215–7 (1938).

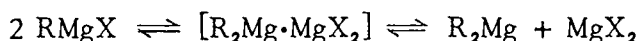
⁴¹(a) Noller and White, *J. Am. Chem. Soc.*, 59, 1354–6 (1937); (b) Noller and Raney, *ibid.*, 62, 1749–51 (1940).

⁴²Schlenk, *Ber.*, 64B, 736–9 (1931).

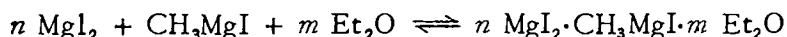
Kullman's⁴³ observations are, in part, confirmatory of those of Noller and White (*loc. cit.*^{41a}). According to Kullman, the addition to an ethereal ethylmagnesium bromide solution of sufficient dioxane to effect complete bromide precipitation leaves only 55-60 percent of the ethyl groups in solution in the form of diethylmagnesium. With time the diethylmagnesium content of the solution increases, the percentage of ether-soluble ethyl groups reaching 70-75 percent in twenty-four hours. Addition of the same amount of dioxane in three or four portions, with about twenty-four hours intervening between each addition and the next, results in bromide precipitation which leaves 93-97 percent of the ethyl groups in ethereal solution in the form of diethylmagnesium.

Recalling Rheinboldt's⁴⁴ preparation of crystalline magnesium iodide dioxanate ($\text{MgI}_2 \cdot 2 \text{C}_4\text{H}_8\text{O}_2$) by the addition of dioxane to an ethereal solution of magnesium iodide, and of the corresponding bromide and chloride dioxanates by more convenient methods, Kullman postulates that $(\text{C}_2\text{H}_5)_2\text{Mg} \cdot \text{C}_4\text{H}_8\text{O}_2$ is ether-soluble, that $\text{Br}_2\text{Mg} \cdot 2 \text{C}_4\text{H}_8\text{O}_2$ is ether-insoluble, and that the amount of dioxane necessary for complete bromide precipitation is three molecular equivalents for each two gram-equivalents of magnesium present. He concludes that no ethylmagnesium bromide is precipitated as such.

Basing their argument on the relative rates and heats of reaction of solutions of methylmagnesium iodide and dimethylmagnesium, respectively, in butyl ether with acetone and with ethyl acetate, Aston and Bernhard⁴⁵ conclude that a butyl ether solution of methylmagnesium iodide contains almost no free dimethylmagnesium. In further support of this conclusion they cite the ready inflammability of dialkylmagnesium solutions and the comparative stability of the corresponding alkylmagnesium halide solutions. They suggest that the Grignard reagent equilibrium be formulated as:



On the basis of their own and Menshutkin's⁴⁶ determinations of the freezing points of ethereal magnesium iodide solutions, and of their own measurements of the freezing points of ethereal methylmagnesium iodide solutions, Stewart and Ubbelohde⁴⁷ propose the equilibrium:



in which n has a probable value of 2. They tentatively formulate the

⁴³Kullman, *Compt. rend.*, 231, 866-8 (1950).

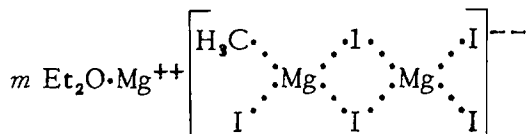
⁴⁴Rheinboldt, Luyken, and Schmittmann, *J. prakt. Chem.*, [2], 149, 30-54 (1937).

⁴⁵Aston and Bernhard, *Nature*, 165, 485 (1950).

⁴⁶Menshutkin, *Z. anorg. Chem.*, 49, 34-45 (1906).

⁴⁷Stewart and Ubbelohde, *J. Chem. Soc.*, 1949, 2649-56.

complex as:



In so far as these arguments need be taken seriously at all, they merely labor the obvious and generally-recognized point that the Schlenk equation constitutes an over-simplified statement.

In view of the limited solubility of magnesium chloride etherate in ether (*ca.* 0.001 mole per 1000 g. of solution),⁴⁸ one might anticipate that organomagnesium chloride solutions would deposit magnesium chloride etherate, and that the disproportionation equilibrium would be shifted far toward the right. Indeed, this phenomenon has been reported by Schlenk and Schlenk (*loc. cit.*³³) as occurring in benzylmagnesium chloride solutions after several days standing. They attributed the delayed precipitation to supersaturation. Cope³⁴ has also found that methylmagnesium chloride solutions deposit magnesium chloride; in this case, the deposition is immediate rather than delayed, but the disproportionation nevertheless remains relatively slight. Noller and Raney have investigated *n*-butylmagnesium chloride solutions under conditions which preclude the possibility of supersaturation (*i.e.*, by shaking with anhydrous magnesium chloride). Under these conditions, a little magnesium chloride is precipitated (3-10 percent of the total chlorine content), whereas the dioxane-precipitation method indicates that about 88 percent of the basic magnesium present is in the form of $(n\text{-C}_4\text{H}_9)_2\text{Mg}$. One must conclude either that the precipitation gives a grossly inaccurate picture of the disproportionation equilibrium or that magnesium chloride etherate is more soluble in the Grignard solution than in ether. In view of the fact that magnesium bromide etherate has been shown to be much more soluble in *n*-butylmagnesium bromide solution than in ether,⁴⁹ the latter seems the more credible conclusion.

A later note by Noller and Castro⁵⁰ indicates that the question may not be merely one of complex solubilities. They found that chloride precipitation from *n*-butylmagnesium chloride is greatly accelerated and increased by oxygen contamination. Indeed, with the most careful precautions to exclude oxygen there is virtually no chloride precipitation in one hundred sixty days. They postulate that ROMgX would carry down some MgCl_2 and be converted eventually to $\text{ROMgX} \cdot 2 \text{MgCl}_2$. However, in the case of benzylmagnesium chloride, they were unable to prevent chloride precipitation even by the most careful precautions against oxygen contamination.

⁴⁸Noller and Raney, *J. Am. Chem. Soc.*, 62, 1749-51 (1940).

⁴⁹Doering and Noller, *J. Am. Chem. Soc.*, 61, 3436 (1939).

⁵⁰Noller and Castro, *J. Am. Chem. Soc.*, 64, 2509-10 (1942).

"Equilibrium" determinations similar to those of Noller and Raney (*loc. cit.*⁴⁸) have been made by Coleman and Brooks⁵¹ on butyl ether solutions of ethylmagnesium and butylmagnesium chlorides.

ELECTROLYTIC PROPERTIES OF GRIGNARD REAGENT SOLUTIONS

Jolibois⁵² observation that ethereal solutions of ethylmagnesium bromide are electrically conducting was confirmed by Nelson and Evans.⁵² Subsequent studies of the conductivities of ethereal ethylmagnesium bromide and iodide and of propyl- and isopropylmagnesium iodides have been made by Kondyrew *et al.*⁵³ In general, the conductivities increase with rising temperature. For the ethyl Grignard reagents, the conductivities pass through a maximum with increasing concentration.

Kondyrew^{53a} also noted that when externally connected magnesium and platinum electrodes are immersed in an ethereal ethyl bromide solution magnesium is dissolved and a potential is set up (0.76 volt under the experimental conditions employed).

Studies on the electrolysis of Grignard reagents have been made by Gaddum and French⁵⁴ (phenylmagnesium bromide, benzylmagnesium chloride), by Rodebush and Peterson⁵⁵ (ethylmagnesium bromide), by French and Drane⁵⁶ (isoamylmagnesium chloride), and by Duval⁵⁷ (phenylmagnesium bromide).

In view of its apparent molecular weight and its electrolytic characteristics, Duval suggests that ethereal phenylmagnesium bromide be formulated as $[\text{MgPh}_2\text{Br}_2(\text{Et}_2\text{O})_2]\text{Mg}$. Decombe and Duval⁵⁸ believe that in such a complex, the anionic magnesium should be replaceable by a less reactive metal such as zinc. By the action of methyl iodide on magnesium-zinc alloy in ethyl ether and in ethyl acetate, they have prepared crystalline compounds which they formulate as $[\text{ZnMe}_2\text{I}_2(\text{Et}_2\text{O})_2]\text{Mg}$ and $[\text{ZnMe}_2\text{I}_2(\text{AcOEt})_2]\text{Mg}$, respectively, and which give analyses consistent with those formulae. Upon hydrolysis, the compounds yield methane, zinc iodide and magnesium hydroxide. Upon electrolysis, magnesium is deposited on the cathode and zinc is transported toward the anode.

⁵¹Coleman and Brooks, *J. Am. Chem. Soc.*, 68, 1620-1 (1946).

⁵²Nelson and Evans, *J. Am. Chem. Soc.*, 39, 82-3 (1917).

⁵³(a) Kondyrew, *Ber.*, 58B, 459-63 (1925); (b) Kondyrew and Manojew, *ibid.*, 58B, 464-7 (1925); (c) Kondyrew, *ibid.*, 61B, 208-12 (1928); *J. Russ. Phys.-Chem. Soc.*, 60, 545-51 (1928); *Chem. Abstr.*, 23, 1321 (1929); (d) Kondyrew and Ssusi, *Ber.*, 62B, 1856-61 (1929); (e) Kondyrew and Zhel'vis, *J. Gen. Chem. (U.S.S.R.)*, 4, 203-8 (1934); *Chem. Abstr.*, 29, 25 (1935).

⁵⁴Gaddum and French, *J. Am. Chem. Soc.*, 49, 1295-9 (1927).

⁵⁵Rodebush and Peterson, *J. Am. Chem. Soc.*, 51, 638-9 (1929).

⁵⁶French and Drane, *J. Am. Chem. Soc.*, 52, 4904-6 (1930).

⁵⁷Duval, *Compt. rend.*, 202, 1184-6 (1936).

⁵⁸Decombe and Duval, *Compt. rend.*, 206, 1024-6; *Chem. Abstr.*, 32, 4940 (1938).

These authors believe that it should be possible to replace cationic magnesium with a more active metal such as calcium, forming compounds which they would formulate as $[\text{MgR}_2\text{X}_2(\text{Et}_2\text{O})_2]\text{Ca}$.

For the most detailed and informative studies in the electrolytic field, we are indebted to Evans and his co-workers.⁵⁹

The data most pertinent to the question of the constitution of the Grignard reagent may be summarized as follows.

1. Magnesium is deposited on the cathode; hydrocarbons and sometimes hydrogen and secondary organic products are liberated in the anode portion of the cell.

2. All concentration losses of solute constituents occur in the cathode portion. The anode portion shows a gain in all solute constituents at all times, even after losing an equivalent amount of R by electrolysis.

3. The relative amounts of R and X gained by the anode portion are not constant, but depend upon the ratio of R to X in the original solution. When the MgX_2 concentration is low, R_2Mg or RMgX is transported to the anode; when the MgX_2 concentration is high, MgX_2 is transported to the anode.

4. The net migration of magnesium to the anode portion shows that it is present in the anion as well as in the cation.

5. There is always a net gain of MgX_2 in the solution.

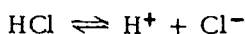
6. Current efficiency is high at low concentrations of the Grignard solution, but falls off with increasing concentration (for CH_3MgBr , 100 percent at 0.27 N; 48 percent at 2.58 N).

Ionization of Grignard reagents. From these observations and previously ascertained facts concerning the properties of Grignard solutions (already summarized in the foregoing resumé), Evans and Pearson (*loc. cit.*^{59h}) have evolved a satisfactory description of the nature of the Grignard solution and the electrolysis process which may be paraphrased as follows.

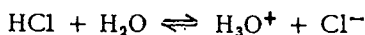
In a suitable medium, the components of the Schlenk equilibrium are capable of ionization in the senses indicated by the following oversimplified* scheme:

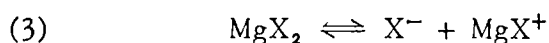
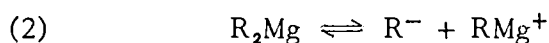
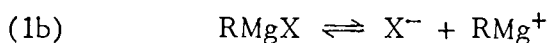
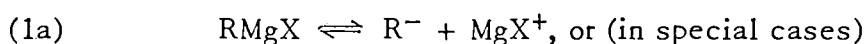
⁵⁹(a) Evans and Lee, *J. Am. Chem. Soc.*, 56, 654-7 (1934); (b) Evans, Lee, and Lee, *ibid.*, 57, 489-90 (1935); Evans and Field, *ibid.*, 58, (c) 720-4, (d) 2284-6 (1936); (e) Evans and Braithwaite, *ibid.*, 61, 898-900 (1939); (f) Evans, Braithwaite, and Field, *ibid.*, 62, 534-6 (1940); (g) Evans, Pearson, and Braithwaite, *ibid.*, 63, 2574-6 (1941); (h) Evans and Pearson, *ibid.*, 64, 2865-71 (1942).

*In part the simplification is equivalent to indicating the ionization of hydrogen chloride in an aqueous medium as



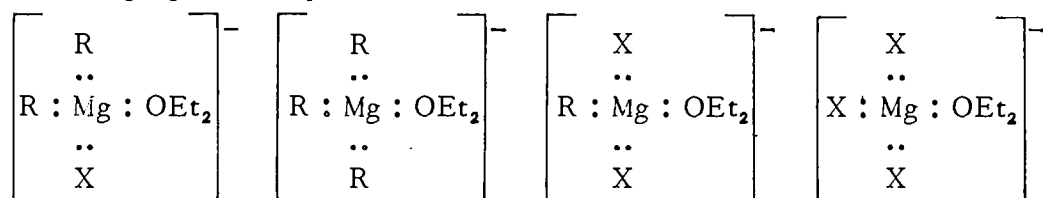
rather than



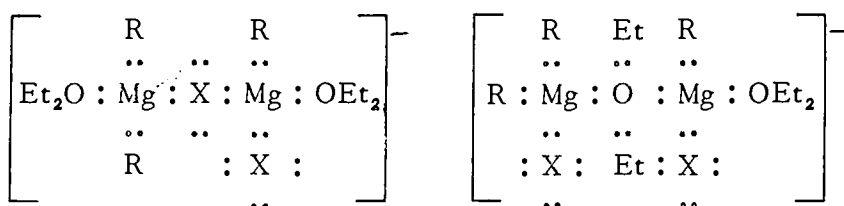


The formation of Mg^{++} ions in ethyl ether solution is regarded as highly improbable, partly because of the very low dielectric constant of the solvent.

The anions, with one or more unshared electron pairs, are bases and hence are not attracted to the electrodotic solvent molecules, but rather to the electrophilic solute molecules. The smallest possible anions present in very dilute Grignard solutions may therefore be represented as belonging to the species:

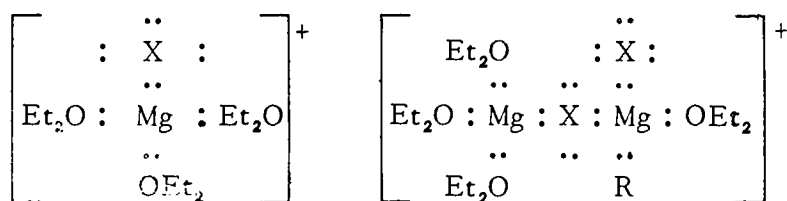


The repulsion of like charges would, of course, prevent mutual association between members of this class, but not between members of this class and positively charged or neutral electron acceptors. The more concentrated the solution, the higher will be the degree of association, and the larger the composite anion. Conceivable modes of secondary association might be represented by:



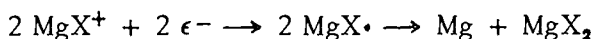
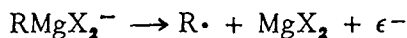
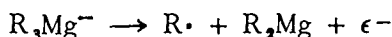
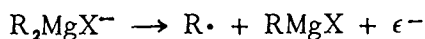
The anions, however large, remain fairly mobile because of their limited attraction for the solvent (one molecule of ether, or less, per atom of magnesium).

The cations, on the other hand, with their great electron deficiency, are highly acidic in the Lewis sense, and are undoubtedly relatively highly solvated by the basic solvent, with a consequent lowering of mobility despite their (probably) smaller average size.



It need scarcely be emphasized that in solvents of low dielectric constant, like ethyl ether, the tendency toward the association of ion-pairs must be very great, and, concordantly, that the actual degree of ionic dissociation must be very small.

Electrolytic discharge of ions. Electrolytic reactions at the anode and cathode, respectively, may be represented in simplified style as follows:



The ultimate fate of the radicals liberated at the anode varies with the nature of the individual radical.

The non-gaseous organic products of the electrolysis of phenylmagnesium bromide have been reported as benzene,⁵⁷ biphenyl,^{54, 59g} terphenyl, higher "polymer," and styrene.^{59g}

For methylmagnesium iodide or bromide in ethyl ether, the corresponding products are methane, ethane, ethylene and isobutylene.^{59a, c} The relative amounts of the products vary with solution concentration and current density. In *n*-butyl ether the products are methane, ethane, butane, butenes, butyl alcohol, and 2-pentanol^{59d}.

The ethylmagnesium halides yield ethane and ethylene in nearly equimolecular proportions, together with a little hydrogen.^{59a}

n-Propylmagnesium bromide yields propane, propylene, hexane, ethylene, hydrogen, ethanol, propanol, methylpropylcarbinol, and diethylcarbinol.^{59a}

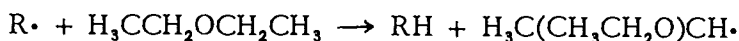
Isopropylmagnesium bromide yields propane, propylene, ethylene, hydrogen, ethanol, isopropyl alcohol, and traces of 2,4-dimethylbutane.^{59e}

t-Butylmagnesium bromide yields chiefly isobutane and isobutylene.^{59f}

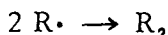
n-Butyl-, isobutyl-, *s*-butyl-, and *n*-hexylmagnesium bromides yield the radical coupling products (R_2) exclusively.^{59f}

It is therefore evident that three courses of action are open to radicals liberated at the anode:

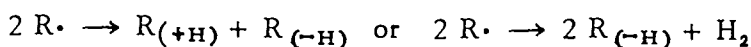
(1) attack upon the solvent, *e.g.*,



(2) coupling,



and (3) disproportionation,



For the more reactive (in general, the more "electronegative"*) free radicals, the tendency to attack the solvent is strong. Indeed, it is doubtful that any of the diphenyl formed in the electrolysis of phenylmagnesium bromide is the result of simple radical coupling, other than that which takes place at the electrode surface. Some of it may be formed by the attack of phenyl radicals upon benzene already formed by attack upon the solvent, or by attack upon the Grignard reagent. Certainly terphenyl and higher "polymers" must have an origin other than simple coupling.

For the somewhat less, but still moderately, active methyl radical, the tendency to attack the solvent is still rather strong, though the liberation of ethane from butyl ether solution and the increase in proportion of ethane liberated at higher concentrations and higher current densities in ethyl ether solution suggest that coupling takes place concurrently, at least at the electrode surface.

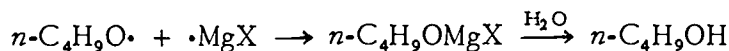
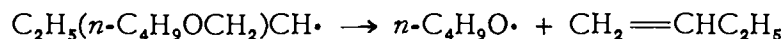
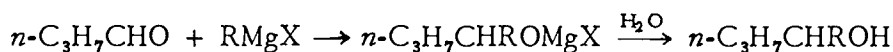
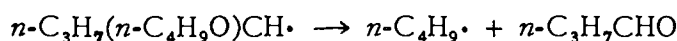
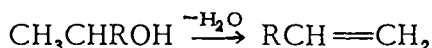
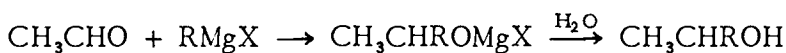
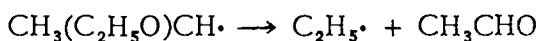
For the slightly less active but much less stable ethyl radical, disproportionation is almost total.

The propyl radical, less active than the ethyl radical, but more stable, couples to the extent of about 50 percent, disproportionates to a somewhat less extent, and attacks the solvent slightly.

The isopropyl and *t*-butyl radicals, both relatively unstable, undergo disproportionation chiefly.

The relatively unreactive, but relatively stable, *n*-butyl, isobutyl, *s*-butyl, and *n*-hexyl radicals couple almost quantitatively (as does the benzyl radical).

Some of the secondary reactions postulated by Evans *et al.* as consequent upon radical attack upon the solvent may be described as follows:

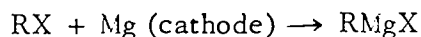
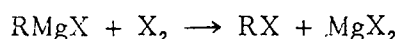
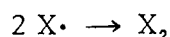
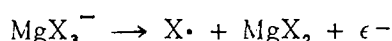
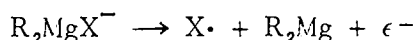
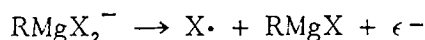


The behavior of radicals liberated by electrolytic neutralization of

*Concerning the relative "electronegativities" of organic radicals see: Kharasch and Reinmuth, *J. Chem. Education*, 5, 404-18 (1928); 8, 1703-48 (1931); Kharasch, Reinmuth, and Mayo, *ibid.*, 11, 82-96 (1934); 13, 7-19 (1936).

anions is, in general, similar to that observed by Kharasch *et al.*⁶⁰ for free radicals generated by the attack of cobaltous chloride on Grignard reagents.

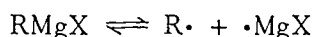
In certain special cases, as has already been suggested, dissociation of the Grignard reagent may take place in the sense $\text{RMgX} \rightleftharpoons \text{X}^- + \text{RMg}^+$. There appears to be some reason to suppose that this may occasionally be true of $\text{C}_6\text{H}_5\text{C}\equiv\text{CMgI}$ ^{59b}. The anodic electrolysis process and sequelae may then be described as follows:



Evans (*loc. cit.*)^{59b} found that the decomposition potential varies with the individual Grignard reagent. For molar solution, the average decomposition voltages observed were: $\text{C}_6\text{H}_5\text{MgBr}$, 2.17; CH_3MgBr , 1.94; $n\text{-C}_3\text{H}_7\text{MgBr}$, 1.42; $n\text{-C}_4\text{H}_9\text{MgBr}$, 1.32; $\text{C}_2\text{H}_5\text{MgBr}$, 1.28; $s\text{-C}_4\text{H}_9\text{MgBr}$, 1.24; $i\text{-C}_3\text{H}_7$, 1.07; $t\text{-C}_4\text{H}_9\text{MgBr}$, 0.97; $\text{H}_2\text{C}=\text{CHCH}_2\text{MgBr}$, 0.86. Although there are minor deviations (scarcely surprising in view of the complexity of relatively concentrated solutions, and the possibility of polarization effects), the trend is unmistakably from relatively high voltages for relatively "electronegative" radicals to low voltages for weakly electronegative radicals.

NON-IONIC DISSOCIATION OF GRIGNARD REAGENTS

In some "normal" reactions of Grignard reagents (as, *e.g.*, those with azo compounds, *q.v.*), and in many so-called "abnormal" reactions (see, *e.g.*, Chapters V and VI) there is obviously homopolar scission of the organometallic bond of the Grignard reagent. In such cases, however, it is usually unnecessary to assume a dissociation equilibrium of the kind suggested by Alexander,⁶¹

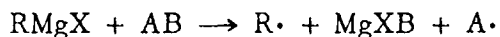


as a prerequisite to reaction. "Forced" (*i.e.*, high-temperature) reactions,

⁶⁰See, *e.g.*: Kharasch and Fields, *J. Am. Chem. Soc.*, 63, 2316-20 (1941); Kharasch and Kleimann, *ibid.*, 65, 491-3 (1943); Kharasch, Lewis, and Reynolds, *ibid.*, 65, 493 (1943); Kharasch, Nudenberg, and Archer, 65, 495-8 (1943); Kharasch, Lewis, and Reynolds, *ibid.*, 65, 498-500 (1943).

⁶¹Alexander, "Principles of Ionic Organic Reactions," John Wiley & Sons, Inc., New York, 1950, p. 188; *c.f.* Chapter V, this monograph.

or those of such atypical reagents as the triphenylmethylmagnesium halides may occasionally involve such dissociations, but in general it appears much more probable that the reactions either (1) proceed by a mechanism that does not involve the actual release of free radicals into the solution, or (2) are initiated by an induced dissociation:

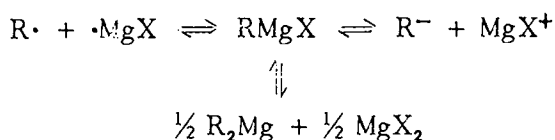


CHAPTER V

Some Radical Reactions of Grignard Reagents

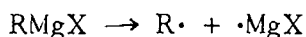
HOMOLYTIC DISSOCIATION

Although the majority of the so-called "normal" Grignard reagent reactions appear to be essentially ionic in nature,* some reactions, especially among those commonly regarded as "abnormal," are most readily explicable upon the basis of the hypothesis that the R-MgX bond undergoes homolytic scission. Such reactions may result in the liberation of free radicals in the reaction system, but the existence of *free* radicals is by no means an essential feature of a radical reaction (*i.e.*, a reaction involving homolytic scission of the R-MgX bond). It is therefore unnecessary, in general, to assume an equilibrium of the type proposed by Alexander,¹



although such equilibria may occur in special cases (as, *e.g.*, those of the triarylmethylmagnesium halides).

It is probable that in some "forced" (*i.e.*, high-temperature) reactions dissociation of the Grignard reagent in the sense



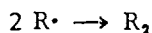
occurs, but in general no equilibrium is attained in such cases because of the reactivity of the radicals R· toward each other† or toward other components of the reaction system (*e.g.*, Et₂O and RMgX).

It appears highly probable, however, that, in general, the homolytic dissociation of the R-MgX bond in Grignard reactions is an induced

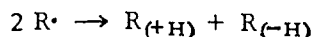
*This statement should not be interpreted as implying that actual dissociation of the reagent into ions is a necessary prelude to reaction. It is sufficient to postulate that heterolytic scission of the R-MgX bond occurs in the course of the reaction.

¹Alexander, "Principles of Ionic Organic Reactions," John Wiley & Sons, Inc., New York, 1950, p. 188.

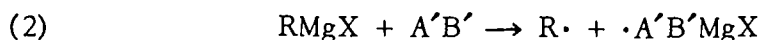
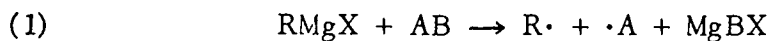
†The commonest reactions of radicals with each other are (irreversible) dimerization,



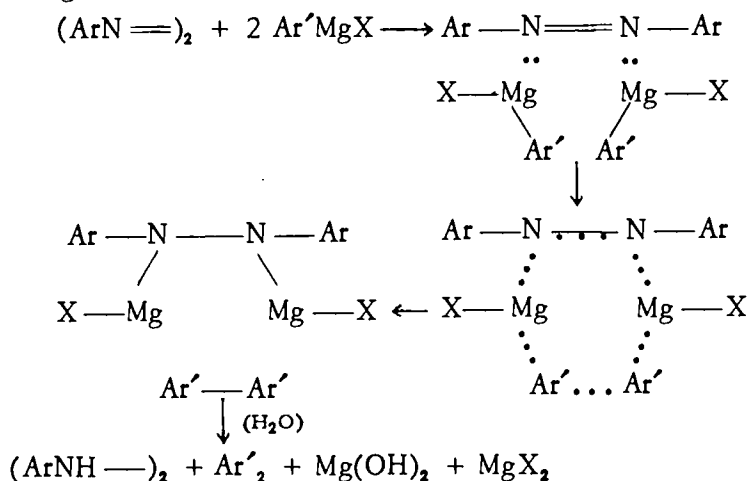
and disproportionation,



phenomenon requiring the participation of a co-reactant. Such induced homolytic dissociations may give rise to the liberation of *free* radicals by, *inter alia*, processes like those represented in equations 1 and 2.



In some radical reactions it appears extremely improbable that any *free* radicals are ever released. The reduction of an azo compound by an arylmagnesium halide is a case in point (see Chapter XIX, Azo Compounds). Although present knowledge of such reactions is inadequate to support any assured statement regarding reaction mechanism, the reaction products invite tentative consideration of some such scheme as the following.

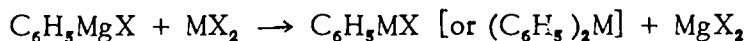


ACTION OF SOME METALLIC HALIDES ON GRIGNARD REAGENTS

Any attempt at a comprehensive review of the reactions of Grignard reagents with metallic halides would extend beyond the projected scope of the present work. Nevertheless, the use of various metallic halides by numerous investigators either as (a) supposed catalysts of "normal" Grignard reactions, or as (b) initiators or facilitators of "abnormal" Grignard reactions compels some attention to this subject.

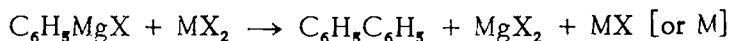
Unfortunately, present knowledge of the reactions of Grignard reagents with metallic compounds is by no means satisfactorily extensive or exact. Save for minor extensions, the brief statement of Gilman and Lichtenwalter² summarizes about all that is presently known with any degree of certainty.

"In general, metallic halides react with Grignard reagents to give organometallic compounds which are less reactive than the RMgX compounds:

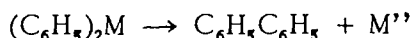


However, there are some metallic halides which react with Grignard reagents to give only a coupling product:

²Gilman and Lichtenwalter, *J. Am. Chem. Soc.*, 61, 957-9 (1939).



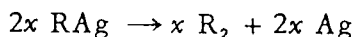
A third, and intermediate, class of metallic halides reacts with RMgX compounds to give highly thermally unstable organometallic compounds which decompose readily to the coupling product and metal:



With reactions that lead to the preparation of relatively stable organometallic compounds the present work is not concerned. Regarding reactions in which thermally unstable organometallic compounds play a part certain points that have been little stressed, or that have been ignored or overlooked altogether, in literature discussions are worthy of passing comment.

Unstable Intermediate Organometallic Compounds. It appears to have been fairly credibly established that organosilver compounds (arising from the interaction of Grignard reagents with silver halides) and organocopper compounds (arising from the interaction of Grignard reagents with cuprous halides, or with cupric halides, which readily undergo Grignard reduction to cuprous compounds) exist, and are relatively stable at low temperatures.^{2,3} Considerable evidence has also been adduced by Hein *et al.*⁴ to indicate that organochromium compounds may be similarly prepared at low temperatures.

Although some investigators have postulated, and others have implied, that the dimerization (*i.e.*, "coupling") of the Grignard reagent radical arising through the decomposition of a thermally unstable organometallic intermediate is a free-radical process, the preponderance of the evidence is strongly to the contrary. The fact that phenylsilver decomposes in ethereal solution to give good yields of biphenyl, with no evidence of attack upon the solvent, would preclude the possibility that any appreciable quantity of *free* phenyl radicals is released into the reaction system.⁵ It must be concluded, therefore, that such thermal decompositions are essentially radical reactions of second (or higher) order, with respect to the organometallic intermediate, in which no *free* radicals participate.*

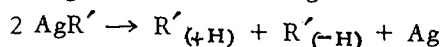


²For contributory evidence and leading references see: Gilman and Parker, *J. Am. Chem. Soc.*, 46, 2823-7 (1924); Gilman and Straley, *Rec. trav. chim.*, 55, 821-34 (1936); Gilman and Lichtenwalter, *loc. cit.*²

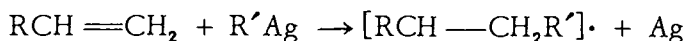
³Hein, *Ber.*, 54B, 1905-38, 2708-27, 2727-44 (1921); Hein and Schwartzkopf, *ibid.*, 57B, 8-14 (1924); Hein and Spaete, *ibid.*, 57B, 899-908 (1924).

⁵See, *e.g.*: Bickley and Gardner, *J. Org. Chem.*, 5, 126-32 (1940).

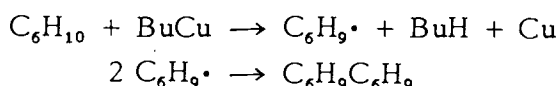
*The fact that the radicals of alkyl Grignard reagents undergo disproportionation as well as dimerization in such reactions does not constitute a cogent argument for the presence of *free* radicals in the system. There would appear to be no valid reason why disproportionation might not take place by a bi- or polymolecular process analogous to that which gives rise to dimerization.



The addition-polymerization reactions initiated by Ziegler *et al.*⁶ in butadiene-phenylmagnesium bromide systems with the aid of silver bromide or cupric chloride, and in styrene-propylmagnesium bromide systems with the aid of silver bromide, are compatible with this conclusion if it be postulated that good radical acceptors (as both butadiene and styrene have been shown to be) are capable of inducing homolytic scission of a relatively unstable organometallic bond.

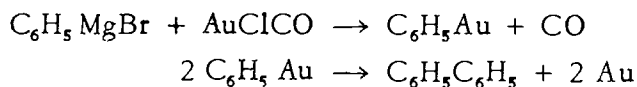


Granted the probability of such induced dissociations (for which there would seem to be ample precedent), the scheme might be extended to include the participation of ready hydrogen donors. It is thus possible to account credibly for the formation of 3,3'-bicyclohexenyl in cyclohexene-butylmagnesium bromide-cupric chloride systems, mentioned, but not described in detail, by Ziegler *et al.* (*loc. cit.*⁶).

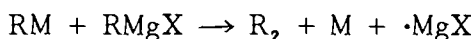


We so make use of the working hypothesis that induced radical reactions may generate derived *free* radicals by either additive or subtractive processes.

Incidentally, the reactions of aurous chloride carbonyl with arylmagnesium halides probably involve unstable organogold compounds. The yields of biaryls obtained with aurous chloride carbonyl are, in general, better than those attainable with silver halides, that with phenylmagnesium bromide being quantitative within the limits of experimental error.⁷



It should be noted, however, that assumption of the validity of the foregoing dimerization schemes does not necessarily preclude the possibility of the occurrence of the following competitive processes:



Reactions of Group VIII (Fe, Co, Ni) Halides. The fact that halides of iron, cobalt, and nickel undergo with Grignard reagents overall reactions formally resembling those of the silver and cuprous halides⁸ suggests that reaction mechanisms for the group VIII metallic halides may be analogous to those for the IB halides, and that the hypothetical organometallic intermediates of the one class may differ from the demonstrated organometallic intermediates of the other class primarily in degree of stability.

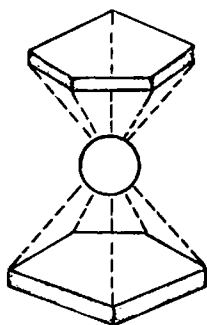
⁶Ziegler, Eimers, Hechelhammer, and Wilms, *Ann.*, 567, 43-96 (1950).

⁷Kharasch and Isbell, *J. Am. Chem. Soc.*, 52, 2919-27 (1930).

⁸Cf. Gilman and Lichtenwalter, *loc. cit.*²

The existence of organoiron compounds has been postulated, and some circumstantial evidence purporting to support the postulation has been presented.⁹ However, with one conspicuous exception, no such compounds have as yet been isolated, and the evidence for their existence, such as it is, may be otherwise interpreted.¹⁰

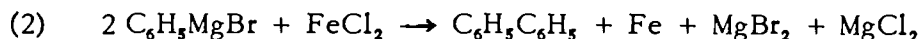
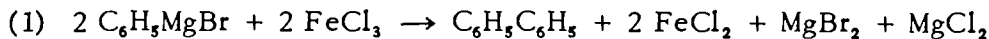
The biscyclopentadienyliron obtained by Kealy and Pauson (*loc. cit.*¹⁰) in the attempt to prepare biscyclopentadienyl by effecting a "coupling" reaction between cyclopentadienylmagnesium bromide and ferric chloride is unique in its stability with respect to thermal decomposition and to the action of water, acid, and alkali. On the basis of various physical measurements and of the aromaticity of the compound, as evidenced by its ability to undergo the Friedel-Crafts reaction with acyl halides, Woodward *et al.*¹¹ deduce the complete equivalency of the methyldyne (CH) groups, and propose the following structure, as well as the name *ferrocene*.



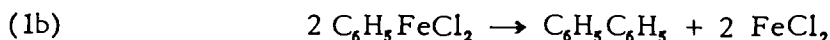
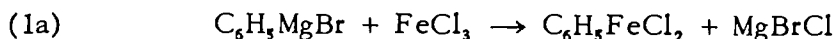
According to Champetier (*loc. cit.*⁹), the overall reaction of phenylmagnesium bromide with ferric chloride,



takes place in two stages which may be represented stoichiometrically as follows:



It is, of course, possible to postulate for the first stage of this oxidation-reduction a process analogous to that proposed for those involving silver and cuprous halides.

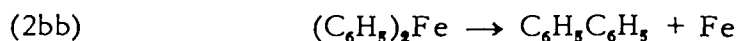


⁹See, *e.g.*, Champetier, *Bull. soc. chim.*, [4], 47, 1131-7 (1930); Krause and von Grosse, "Die Chemie der metal-organischen Verbindung," Berlin, 1937, pp. 784-6.

¹⁰See, *e.g.*, Kealy and Pauson, *Nature*, 168, 1039-40 (1951).

¹¹Wilkinson, Rosenblum, Whiting, and Woodward, *J. Am. Chem. Soc.*, 74, 2125-6 (1952); Woodward, Rosenblum, and Whiting, *ibid.*, 74, 3458-9 (1952).

The second stage of the oxidation-reduction might be hypothetically represented in various ways, of which the following are illustrative.



The statement of Oddo,¹² unaccompanied by supporting detail, to the effect that alkylmagnesium halides differ from the corresponding aryl reagents in their behavior toward ferric chloride in that the principal organic product is an alkyl chloride rather than a biaryl, invites further investigation. The reaction is formulated by Oddo as follows:



Confident interpretation of the reactions of any of the group VIII halides with Grignard reagents must await more intensive (and extensive) study with the aid of techniques more refined than those hitherto applied to investigations in this field.

The reactions of nickel chloride ($NiCl_2$) with Grignard reagents have received somewhat less attention than those of the iron chlorides. At present writing the gross picture for nickel chloride would appear to resemble that for cobaltous chloride more closely than that for ferrous chloride, although it is conceivable that all these reactions differ from one another in degree rather than in kind.

Under the circumstances it would be idle to speculate upon the courses of reactions in which it is reported that a system comprising ethereal phenylmagnesium bromide and nickel chloride absorbs ethylene,¹³ or that a system comprising ethereal phenylmagnesium bromide and ferric chloride absorbs several molecular equivalents of acetylene.¹⁴ As rather sketchily described, these reactions have the appearance of processes involving radical transfer, though not necessarily of processes involving *free* radicals.

Polya and Ingles¹⁵ have added ethereal Grignard reagent solutions to ethereal solutions of cobaltous bromide and cobaltous iodide, obtaining dark-colored precipitates which were separated and then extracted with benzene. The benzene-extraction residues contained no metallic cobalt. Precipitates obtained by dilution of the benzene extracts with ligroin

¹²Oddo, *Gazz. chim. ital.*, 44, 11, 268-78 (1914); *Chem. Abstr.*, 9, 795 (1915); *Chem. Zentr.*, 1915, 1, 743.

¹³Job and Reich, *Compt. rend.*, 179, 330-2 (1924); *Chem. Abstr.*, 19, 236 (1925).

¹⁴Job and Champetier, *Compt. rend.*, 189, 1089-91 (1929); *Chem. Abstr.*, 24, 1616 (1930); *Bull. soc. chim.*, [4], 47, 279-89 (1930).

¹⁵Polya and Ingles, *Nature*, 164, 447 (1949); Ingles and Polya, *J. Chem. Soc.*, 1949, 2280-2.

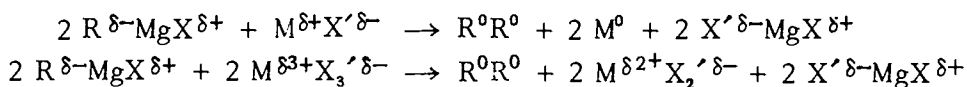
were analyzed. Polya and Ingles correlate their analytical data with such empirical formulations as $(1\text{-C}_{10}\text{H}_7)_3\text{CoI}$, $(1\text{-C}_{10}\text{H}_7)_2\text{CoI}_2$, $(2\text{-C}_{10}\text{H}_7)\text{COBr}_2$, $\text{C}_6\text{H}_5\text{CoBr}_3 \cdot \text{C}_6\text{H}_6$, $\text{CH}_3\text{CoI}_3 \cdot (\text{C}_6\text{H}_5)_2$, $\text{C}_3\text{H}_7\text{CoI}_3 \cdot \text{C}_6\text{H}_6$, etc., and interpret their findings as indicative of the existence of organocobalt compounds. It should be noted, however, that the ligroin precipitates analyzed are not identical with those originally formed, for the analytical samples are virtually insoluble in benzene.

It may also be noted in passing that arguments for the existence of monovalent cobalt, based primarily on analytical data, have been advanced.¹⁶

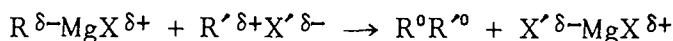
At the present writing, however, it must be admitted that the principal argument in favor of the transitory existence of organocobalt compounds or cobaltous subhalides is the utility of the working hypothesis based thereupon. Because a considerable number of induced Grignard reactions effected with the aid of cobaltous halides may be rather plausibly interpreted in terms of that working hypothesis a separate section is devoted to the topic.

SOME REACTIONS INDUCED BY COBALTOUS HALIDES*

The overall "coupling" reactions described in the preceding sections, and documented in Table V-I, may be regarded as oxidation-reduction reactions in which the Grignard reagent (or, more specifically, the organic group of the Grignard reagent) plays the rôle of reductant. This generalization may be expressed in formal equations such as the following:



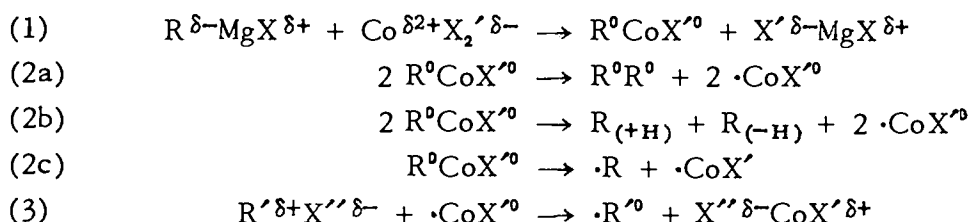
Similarly, the oxidation-reduction aspect of the "normal" condensation of a Grignard reagent with an organic halide may be emphasized in the formal equation:



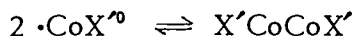
It is interesting that various metallic halides (notably cobaltous halides) may be impressed into service as go-betweens in effecting fundamentally analogous Grignard oxidation-reduction processes which proceed extremely slowly, if at all, under ordinary reaction conditions. The working hypothesis adopted by the present authors to elucidate such relayed, or induced, oxidation-reduction processes may be illustrated for one type of example by the following formal equations:

¹⁶For references see: Mellor, "A Comprehensive Treatise on Inorganic and Theoretical Chemistry," Longmans, Green and Co., New York, Vol. XIV, 1935, p. 525.

*See also: Chapter XVI, Induced "Coupling" Reactions.

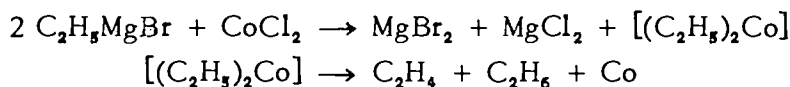


Whereas these equations admittedly depict a mental construct justified primarily by its utility, it is of minor importance whether the expression $2 \cdot CoX'^0$ be accepted literally, whether it be interpreted as indicative of a potential equilibrium,



or whether it be regarded as equivalent to a relatively unstable dimer highly susceptible to induced homolytic dissociation.

In fairness to the reader, and in justice to Wilds and McCormack¹⁷ it should be noted that these investigators have proposed an alternative reaction scheme, postulating an unstable diorganocobalt compound as an ephemeral intermediate, and a highly reactive (colloidal) form of metallic cobalt as the active reducing agent. As applied to reactions involving ethylmagnesium bromide and cobaltous chloride, the proposal of Wilds and McCormack may be expressed as follows:



Aside from pride of parenthood (by no means a negligible consideration), the present authors prefer the scheme originally proposed, chiefly on the ground that the position of cobalt in the periodic system and in the electromotive series raises grave *a priori* doubt that it is (in whatever physical state) a sufficiently active metal to participate in some of the Wurtz-type and ketyl-formation reactions that must be attributed to it. In this connection it may be noted that in a reaction involving phenylmagnesium bromide and bromobenzene, in which cobaltous chloride to the amount of a few mole percent was highly effective, pyrophoric metallic cobalt, even in equivalent quantities, was found to have no effect whatever.¹⁸ This observation is, of course, irrelevant if the colloidal metallic cobalt of Wilds and McCormack is, in fact, significantly more active than pyrophoric cobalt.

Other reactions in which the present authors doubt that cobalt is a sufficiently active metal to serve as the effective reducing agent are the reductions of azobenzene and hydrazobenzene to aniline by a Grignard reagent in the presence of cobaltous chloride (unpublished work, University of Chicago). It seems more probable that reductive cleavage of the

¹⁷Wilds and McCormack, *J. Org. Chem.*, 14, 45-55 (1949).

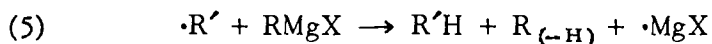
¹⁸Kharasch and Fields, *J. Am. Chem. Soc.*, 63, 2316-20 (1941).

nitrogen-to-nitrogen bond takes place as follows:



So far as existing *direct* evidence is concerned, the reader need feel no compulsion to reject one proposed scheme in favor of the other. In the ensuing discussion, however, the present authors will continue to use the scheme preferred by them.

Behavior of Free Radicals in Solution. The ultimate fate of the free radical $\cdot\text{R}^\circ$ (of Equation 3) is determined primarily by the nature of the free radical itself, and secondarily by the nature of the reaction medium. In general, the more reactive (*i.e.*, the more "electronegative"¹⁹) free radicals may be expected to react with some component of the reaction system. In the simplest cases for Grignard systems such reactions are usually abstractive (of labile hydrogen atoms, or of radicals).



If to the reaction system there is added (either by concurrent reaction processes, or by intention) a more complaisant hydrogen donor than ethyl ether, or if the ethereal solvent is replaced in whole or in large part, by another hydrogen donor, labile hydrogen atom abstraction in the sense of equation 4a may take place.



Examples of the latter type of reaction are to be found in the formation of bi- α -cumyl (α, α' -dimethylbibenzyl, 2,3-dimethyl-2,3-diphenylbutane) when an alkylmagnesium bromide, an alkyl bromide, and cobaltous chloride interact in the presence of cumene (isopropylbenzene).²⁰

Free radicals less reactive (*i.e.*, less "electronegative") than the methyl do not appear to react extensively with ethyl ether or with most Grignard reagents at the boiling point of an ethereal Grignard reaction system. In the absence of a more liberal hydrogen donor (than ethyl ether), such radicals, if structurally incapable of disproportionation, usually dimerize.



Of the free radicals structurally capable of disproportionation, the lower primary aliphatic radicals disproportionate predominantly,²¹ al-

¹⁹Concerning relative "electronegativities" of organic radicals, see: Kharasch and Reinmuth, *J. Chem. Education*, 5, 404-18 (1928); 8, 1703-48 (1931); Kharasch, Reinmuth, and Mayo, *ibid.*, 11, 82-96 (1934); 13, 7-19 (1936).

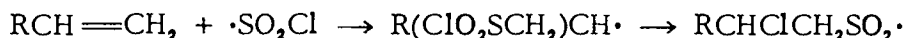
²⁰Kharasch and Urry, *J. Org. Chem.*, 13, 101-9 (1948).

²¹See, *e.g.*, Kharasch, Lewis, and Reynolds, *J. Am. Chem. Soc.*, 65, 493-5 (1943).

though this would not appear at first glance to be the thermodynamically favored course of reaction.* Some, at least, of the secondary radicals (e.g., *s*-butyl, cyclohexyl)²² disproportionate in part and dimerize in part. By extension from the results of peroxide-induced free-radical reactions, and from unpublished results of Grignard free-radical studies in the laboratories of the University of Chicago, it may be expected that the higher aliphatic radicals (say, above hexyl) will also disproportionate in part and dimerize in part. Relatively unreactive resonance-stabilized free radicals (such as the benzyl) may, in general, be expected to dimerize completely. Examples are to be found in the α -cumyl (α,α -dimethylbenzyl) radical (see Kharasch and Urry, *loc. cit.*²⁰) and the α -ethyl-*p*-methoxybenzyl radical.²³

It should be noted, however, that although resonance-stabilization may be a sufficient, it is by no means a necessary condition for radical dimerization, as witness the dimerizations of cyclohexyl and bornyl free radicals (Kharasch, Engelmann, and Urry, *loc. cit.*²²).

Although the phenomenon, presumably, is relatively rare, account must also be taken of the possibility of free-radical rearrangement. It has been shown in studies of peroxide-induced free-radical reactions that the simpler alkyl radicals (specifically, propyl and isopropyl²⁴) do not rearrange. However, there is also evidence strongly suggestive that more complicated heteroelementary radicals may undergo rearrangement.²⁵



The first example, so far as the present authors are aware, of the rearrangement of a hydrocarbon radical in a Grignard free-radical reaction was observed when phenylmagnesium bromide was treated with a catalytic quantity of cobaltous chloride and *ca.* one equivalent of neophyl chloride (1-chloro-2,2-dimethyl-3-phenylpropane).²⁵ The products of the reaction (in addition to biphenyl) are cumene (isopropylbenzene), β -methallylbenzene, 2-methylpropenylbenzene, and a mixture of isomeric neophyl dimers $[(\text{C}_{10}\text{H}_{13}-)_2]$. It appears, therefore, that, either prior to or simultaneously with disproportionation (and dimerization) some rearrangement of the neophyl radical must occur.

*For example, it may be calculated, without resort to assumptions concerning the heat of vaporization of carbon, that ΔH_0° for the reaction $2 \text{C}_2\text{H}_5\cdot \rightarrow \text{C}_2\text{H}_6 + \text{C}_2\text{H}_4$ is of the order of -62 kcal./mole, whereas ΔH_0° for the reaction $2 \text{C}_2\text{H}_5\cdot \rightarrow n\text{-C}_4\text{H}_{10}$ is of the order of -83 kcal./mole.

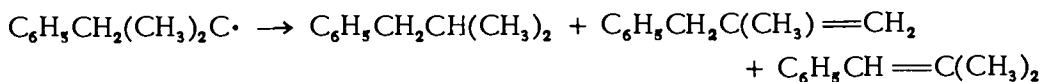
²²See, e.g., Kharasch, Engelmann, and Urry, *J. Am. Chem. Soc.*, 66, 365-7 (1944).

²³Kharasch and Kleiman, *J. Am. Chem. Soc.*, 65, 491-3 (1943).

²⁴Kharasch, Kane, and Brown, *J. Am. Chem. Soc.*, 63, 526-8 (1941).

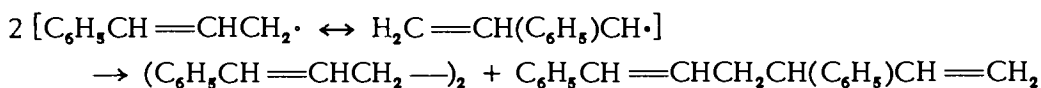
²⁵Kharasch and Zavist, *J. Am. Chem. Soc.*, 73, 964-7 (1951).

²⁶Urry and Kharasch, *J. Am. Chem. Soc.*, 66, 1438-40 (1944).



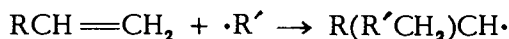
Examples of rearrangements involving hydrogen migrations are to be found in the disproportionations of the γ -phenylpropyl and n -butyl radicals. The principal unsaturated products of these reactions are, respectively, *trans*- β -methylstyrene (rather than allylbenzene) and *trans*-2-butene (rather than 1-butene).²⁷

Although it does not involve a true radical rearrangement, an example of the so-called allylic rearrangement (see Chapter XVII) is to be found in the cobaltous chloride-induced coupling of the free radical derived from cinnamyl chloride. When cinnamyl chloride is treated with methylmagnesium bromide the "normal" condensation product, 1-butenylbenzene, is obtained in *ca.* 89 percent yield. When, however, *ca.* 5 mole percent of cobaltous chloride is added to the reaction system, the yield of "normal" product is reduced to *ca.* 12 percent, and the "coupling" products, 1,6-diphenyl-1,5-hexadiene (*ca.* 30 percent) and 1,4-diphenyl-1,5-hexadiene (*ca.* 40 percent), are obtained in yields aggregating approximately 70 percent (Kharasch *et. al, loc. cit.*²⁷).



Incidentally, nickel chloride (NiCl_2) and chromic chloride (CrCl_3) appear to be about as effective as cobaltous chloride in the induction of this reaction; manganous chloride (MnCl_2) and ferric chloride (FeCl_3) are similarly, but much less, effective.

From the results of numerous studies of photochemical and peroxide-induced free-radical reactions it may be further deduced that when suitable radical acceptors are present in Grignard reaction systems there is the possibility that any free radicals generated may react, at least in part, additively, *e.g.*:

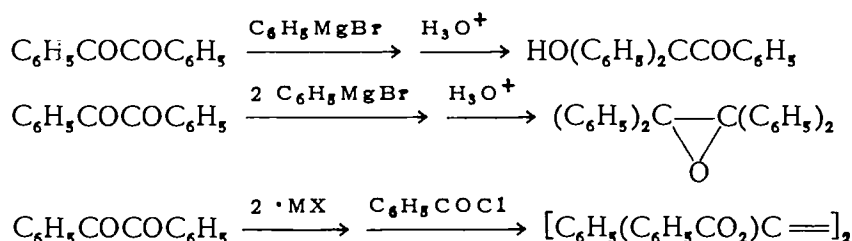


Coupling of Acyl Radicals. It is, perhaps, worthy of explicit mention that, whereas coupling (or disproportionation) of the organic group of a Grignard reagent through the agency of a cobaltous halide requires a stoichiometrically equivalent quantity of the halide, addition to the reaction system of an organic halide converts the process to a chain reaction in which the original cobaltous halide or its equivalent is continually regenerated, and thus functions as a true catalyst. That the catalyst is gradually consumed by side reactions (probably chiefly through reduction to metallic cobalt) is beside the point.

Acyl, as well as alkyl, cycloalkyl, aralkyl, and aryl halides, are susceptible to halogen abstraction by cobaltous subhalides. For example,

²⁷Kharasch, Lambert, and Urry, *J. Org. Chem.*, 10, 298-306 (1945).

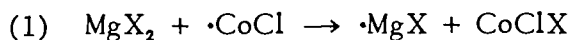
when 0.31 mole of benzoyl chloride was treated with an ethereal solution of 0.35 mole of phenylmagnesium bromide containing 2 mole percent of cobaltous chloride, the products (in addition to biphenyl, benzoic acid, ethyl benzoate, and benzophenone) were α -benzoylbenzhydrol, tetraphenylethylene oxide, and α - β -dibenzoxystilbene.²⁸ For the latter three products benzil, formed by the dimerization of benzoyl radicals, is obviously the substrate.



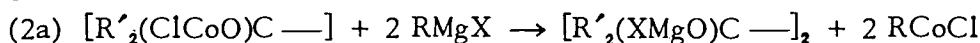
Similar coupling of the mesitoyl radical when mesitoyl chloride is treated with methyl- or phenylmagnesium bromide in the presence of catalytic quantities of cobaltous chloride has been reported²⁹ (see Chapter IX, Coupling).

Metallic Subhalide Reduction of Ketones. The one-electron reduction of a ketone to the corresponding pinacol by a metallic subhalide (see Chapter VI, Magnesium Halide Reduction) may also be effected by means of a chain reaction through the agency of a cobaltous halide.* For example, methylmagnesium bromide reacts "normally" with benzophenone to give a nearly quantitative (*ca.* 95 percent) yield of 1,1-diphenylethanol (α -methylbenzhydrol). When, however, about 2 mole percent of cobaltous chloride is present in the reaction system the yield of "normal" addition product drops to about 2 percent, and benzopinacol is obtained in *ca.* 93 percent yield.³⁰

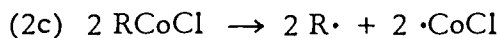
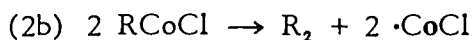
In such reactions the regeneration of cobaltous halide might conceivably take place in either of two ways:



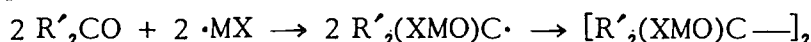
or



or



The ketyl radical dimerization, therefore, is best described by the generalized equation:



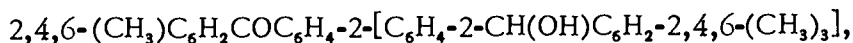
²⁸Kharasch, Nudenberg, and Archer, *J. Am. Chem. Soc.*, 65, 495-8 (1943).

²⁹Kharasch, Morrison, and Urry, *J. Am. Chem. Soc.*, 66, 368-71 (1944).

*Incidentally, ferric chloride is similarly, though less, effective in such reactions.

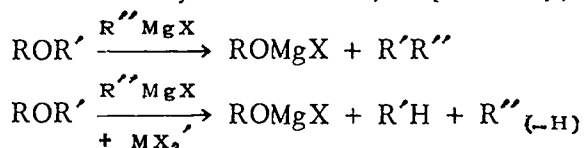
³⁰Kharasch and Lambert, *J. Am. Chem. Soc.*, 63, 2315-6 (1941).

It has been shown by Fuson and Hornberger³¹ that the dimerization of the ketyl radical derived from a "highly hindered" ketone (specifically, benzoylmesitylene) takes an unusual course, yielding, in this instance, mesityl 2'-(mesitylhydroxymethyl)-2-biphenyl ketone,



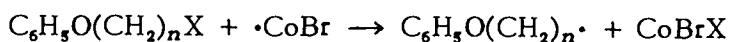
rather than the expected pinacol (see Chapter VI, Magnesium Halide Reduction, and Chapter IX, "Coupling").

Hydrogen Cleavage of Ethers. Whereas the ordinary Grignard reagent cleavage of an ether in the absence of metallic (other than magnesium) halides appears to be an essentially ionic solvolytic reaction (see Chapter XV, Cleavages of Acyclic Ethers), the cleavage of an ether by a potentially reducing Grignard reagent (*i.e.*, one having a labile *beta* hydrogen atom) in the presence of a stoichiometrically equivalent quantity of a suitable metallic halide has rather the appearance of a hydrogenolysis. The two types of reactions may be described, respectively, by the equations:



For example, when phenyl benzyl ether is treated at room temperature with four molecular equivalents of *n*-butylmagnesium bromide in the presence of two molecular equivalents of cobaltous chloride, phenol is obtained in 86 percent yield; the other products are toluene and butene.³² In such reactions nickel chloride and ferric chloride are similarly, though somewhat less, effective.

Reactions of ω -Haloalkyl Phenyl Ethers. Available data on the cobaltous bromide-induced reactions of ω -haloalkyl phenyl ethers with Grignard reagents³³ are not strictly comparable with those of the study just cited,³² for they involve for the most part phenylmagnesium bromide (a non-reducing Grignard reagent) and isopropylmagnesium bromide (a fair reducing agent) rather than *n*-butylmagnesium bromide (a moderately good reducing agent). In any case, however, it would appear that these reactions should be regarded as special cases of the alkyl halide type of reaction rather than typical ether cleavages. Although details of reaction mechanism are still obscure, the primary point of attack would seem to be the *omega* halogen atom.

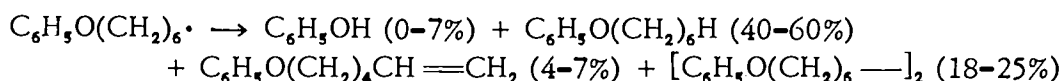
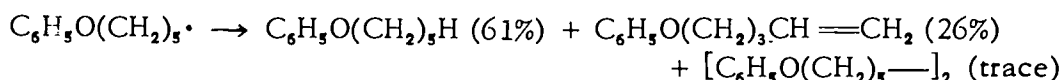
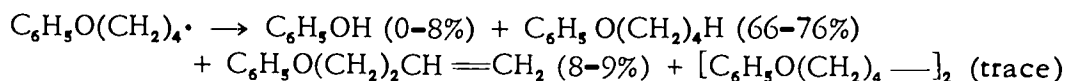
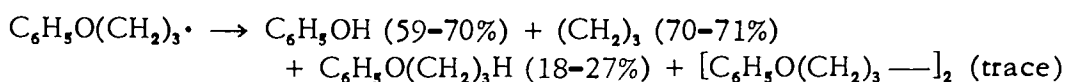
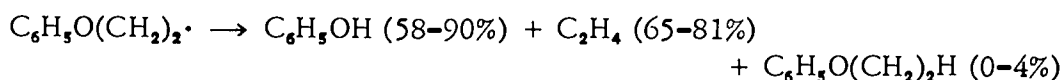


Without any further implications as to reaction mechanisms, the products isolated in a series of such reactions may be indicated as follows:

³¹Fuson and Hornberger, *J. Org. Chem.*, 16, 631-6 (1951).

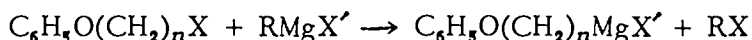
³²Kharasch and Huang, *J. Org. Chem.*, 17, 669-77 (1952).

³³Kharasch, Stampa, and Nudenberg, unpublished work.

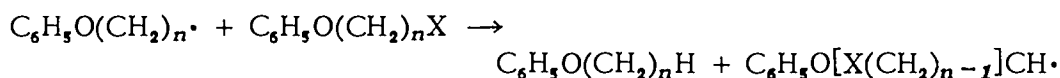


The variation in fate of $\text{C}_6\text{H}_5\text{O}(\text{CH}_2)_n\cdot$ radicals with variation in n is noteworthy. When n is two or three the principal course of reaction involves dissociation (either induced or spontaneous).

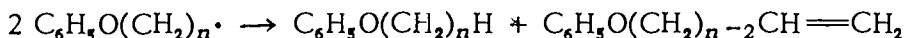
When n is four or five there appears to be some disproportionation, but the marked excess of saturated ether over unsaturated ether suggests either attack upon some relatively liberal hydrogen donor in the reaction system or a considerable amount of induced functional exchange in the sense,



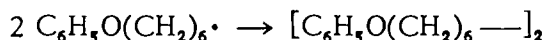
or both. Whereas it appears highly improbable (in view of the behavior of alkyl radicals other than methyl) that such radicals are sufficiently reactive to attack ethyl ether, the most probable candidate for hydrogen donor, other than the $\text{C}_6\text{H}_5\text{O}(\text{CH}_2)_n\cdot$ radical itself, would appear to be the original haloalkyl phenyl ether.



Moreover, it cannot be taken for granted that all the unsaturated ether formed is the product of simple radical disproportionation.



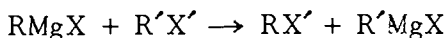
When n is six there is still predominant formation of saturated and unsaturated ethers (with saturated ether in excess) together with considerable apparent dimerization. It seems probable that the coupling product is attributable principally to simple radical combination.



In this connection it may be noted, for what the observation is worth, that when 1-bromohexane was treated with methylmagnesium bromide and cobaltous bromide, (save for traces of nonane) only hexane and hexene were formed; no dodecane could be detected (Khârasch, Stampa, and Nudenberg, *loc. cit.*³³). So far as the present authors are aware, the reaction of n -hexylmagnesium bromide with 1-bromohexane has not been carefully studied.

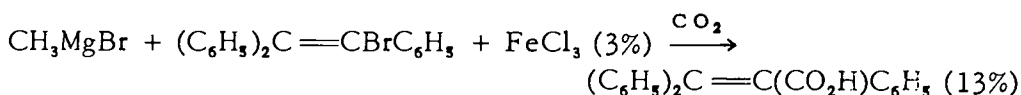
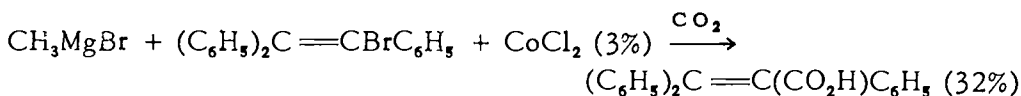
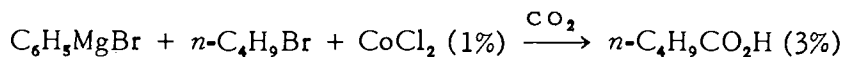
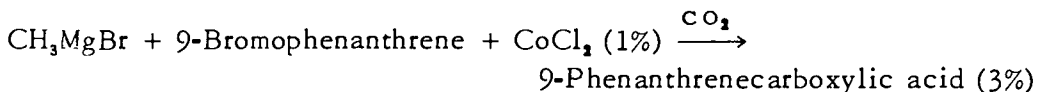
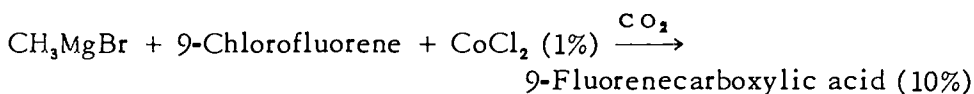
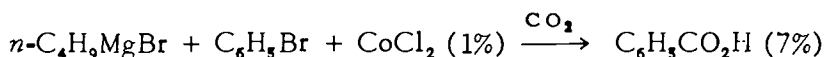
Similar results have been obtained with 1-bromoöctane. The more stable secondary radical derived from 2-bromoöctane, however, does undergo appreciable dimerization. Possibly the phenoxy group in $C_6H_5O(CH_2)_6\cdot$ has a stabilizing effect.

Functional Exchange.* Aside from reductive enolizations of α -halo ketones (*q.v.*), giving rise to enolates that behave like Grignard reagents, and halogen displacements of 1-bromoethynes and some heterocyclic halides (analogous to hydrogen displacements), evidence of uncatalyzed functional exchange in the sense

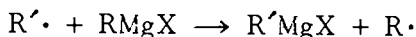


is dubious, to say the least.

It is possible, however, by operating at low temperature (-5 to 0°), and by carbonating the resultant reaction mixture, to demonstrate for some $RMgX \cdot R'X'$ pairs an appreciable degree of exchange (as evidenced by $R'CO_2H$ isolation) when a small amount (*ca.* 1 mole percent) of cobaltous chloride is present in the reaction system.³⁴ Ferric chloride appears to be similarly, though perhaps somewhat less, effective. For example:



Save that such exchanges are not the simple metathetical processes that the definitive equations heretofore employed might seem to imply, little can be said with certainty about the reaction mechanisms involved. Conceivably a free-radical attack on the Grignard reagent in the sense



takes place.

Supplementary Bibliography. Some studies of the effects of cobaltous and other metallic halides on the courses of Grignard reactions not specifically cited in the foregoing discussion are as follows:

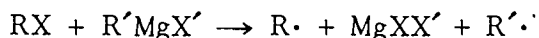
*See also Chapter XVI, Functional Exchange.

³⁴Kharasch and Fuchs, *J. Org. Chem.*, 10, 292-7 (1945).

Kharasch, Kleiger, Martin, and Mayo, *J. Am. Chem. Soc.*, 63, 2305-7 (1941);
 Kharasch and Tawney, *J. Am. Chem. Soc.*, 63, 2308-15 (1941);
 Kharasch and Sayles, *J. Am. Chem. Soc.*, 64, 2972-5 (1942);
 Kharasch and Reynolds, *J. Am. Chem. Soc.*, 65, 501-4 (1943);
 Kharasch and Fuchs, *J. Am. Chem. Soc.*, 65, 504-7 (1943);
 Kharasch, Sayles, and Fields, *J. Am. Chem. Soc.*, 66, 481-2 (1944);
 Kharasch and Tawney, *J. Am. Chem. Soc.*, 67, 128-30 (1945).

UNCATALYZED "COUPLING" REACTIONS*

Numerous reactions in which a susceptible organic halide (suitably an arylated methyl halide), treated with a homolytically dissociable Grignard reagent (suitably methylmagnesium iodide), yields a product attributable to dimerization of the free radical derived from the organic halide have been reported (see Tables XVI-I and IX-II), notably by Fuson *et al.*³⁵ That homolytic dissociation of the Grignard reagent in such reactions is not a unimolecular thermal process of the type $\text{RMgX} \rightarrow \text{R}\cdot + \cdot\text{MgX}$ is strongly suggested by at least two considerations. (1) Analytical studies by Grignard³⁶ and by Blaise³⁷ indicate that ethereal Grignard reagents such as methyl- or ethylmagnesium iodide may be heated (for purposes of desolvation) for considerable periods of time to temperatures as high as 150° without significant decomposition, whereas many "coupling" reactions take place at the boiling point of an ethyl ethereal solution (*ca.* 40°). (2) The occurrence of "coupling" depends, not upon the nature of the Grignard reagent alone, but to a great extent upon the nature of the organic halide also, being especially favored in the cases of halides capable of yielding resonance-stabilized free radicals. The present authors conclude, therefore, that in such reactions free radicals are generated by the mutually induced homolytic dissociations of the Grignard reagent *and* the organic halide.



It is of incidental interest in this connection that relayed or indirect coupling may be effected without the intervention of a metallic halide when ethyl-, *n*-propyl-, or isopropylmagnesium bromide is heated, together with the corresponding alkyl bromide, in cumene to about 100° (the "coupling" product being bi- α -cumyl). Methylmagnesium bromide is too

*See also: Chapter XVI, "Coupling" Reactions; Chapter IX, Other "Abnormal" Reactions.

³⁵(a) Fuson, *J. Am. Chem. Soc.*, 48, 830-6 (1926); Fuson and Ross, *ibid.*, 55, 720-3 (1933); Ellingboe and Fuson, *ibid.*, 55, 2960-6 (1933); Fuson, Denton, and Kneisley, *ibid.*, 63, 2652-3 (1941); Fuson, Chadwick, and Ward, *ibid.*, 68, 389-93 (1946); Fuson, Kneisley, Rabjohn, and Ward, *ibid.*, 68, 533 (1946); Fuson, Denton, and Best, *J. Org. Chem.*, 8, 64-72 (1943); (b) Fuson and Corse, *J. Am. Chem. Soc.*, 60, 2063-6 (1938).

³⁶Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).

³⁷Blaise, *Compt. rend.*, 132, 839-41 (1901); *Chem. Zentr.*, 1901, I, 1000.

stable to effect "coupling" under such conditions (Kharasch and Urry, *loc. cit.*²⁰).

In general it may be expected that the order of susceptibility to homolytic scission among organomagnesium halides will be: iodides > bromides > chlorides. As regards the organic group of the Grignard reagent, low "electronegativity" is more conducive to homolytic dissociation than high "electronegativity," with resonance stabilization of the radical being an especially predisposing factor.

TABLE V-I
SOME REACTIONS OF GROUP IB AND GROUP VIII HALIDES WITH GRIGNARD REAGENTS

<u>Metallic Halide</u>	<u>Grignard Reagent(s)</u>	<u>Product(s)</u>	<u>Ref.</u>
AgCl	C ₆ H ₅ MgBr	C ₆ H ₅ Ag $\xrightarrow{\Delta}$ C ₆ H ₅ C ₆ H ₅ (27.5%) + Ag	1
AgCl	ArMgBr*	ArAg $\xrightarrow{\Delta}$ Ar ₂ + Ag	1
AgBr (1.0 mole)	CH ₃ MgBr (0.5 mole) + C ₆ H ₅ MgBr (0.5 mole)	CH ₃ C ₆ H ₅ (4.0 g., 0.044 mole) + C ₆ H ₅ C ₆ H ₅ (17.0 g., 0.110 mole)	2
AgBr (1.0 mole)	CH ₃ MgBr (0.5 mole) + C ₆ H ₅ CH ₂ MgCl (0.5 mole)	C ₂ H ₅ C ₆ H ₅ (1.0 g., 0.010 mole) + C ₆ H ₅ CH ₂ CH ₂ C ₆ H ₅ (29.0 g., 0.160 mole)	2
AgBr (1.0 mole)	C ₂ H ₅ MgBr (0.5 mole) + C ₆ H ₅ MgBr (0.5 mole)	C ₂ H ₅ C ₆ H ₅ (10.0 g., 0.095 mole) + C ₆ H ₅ C ₆ H ₅ (13.0 g., 0.085 mole)	2
AgBr (1.0 mole)	C ₂ H ₅ MgBr (0.5 mole) + C ₆ H ₅ CH ₂ MgCl (0.5 mole)	<i>n</i> -C ₃ H ₇ C ₆ H ₅ (3.0 g., 0.060 mole) + C ₆ H ₅ CH ₂ CH ₂ C ₆ H ₅ (29.0 g., 0.160 mole)	2
AgBr (2.0 moles)	<i>n</i> -C ₃ H ₇ MgBr (1.0 mole) + C ₆ H ₅ MgBr (1.0 mole)	<i>n</i> -C ₃ H ₇ C ₆ H ₅ (46.0 g., 0.384 mole) + C ₆ H ₅ C ₆ H ₅ (27.0 g., 0.180 mole) + C ₆ H ₁₄ (1.0 g., 0.012 mole)	2
AgBr (1.0 mole)	<i>n</i> -C ₃ H ₇ MgBr (0.5 mole) + C ₆ H ₅ CH ₂ MgCl (0.5 mole)	<i>n</i> -C ₄ H ₉ C ₆ H ₅ (1.3 g., 0.020 mole) + C ₆ H ₅ CH ₂ CH ₂ C ₆ H ₅ (28.0 g., 0.155 mole)	2
AgBr (2.0 moles)	<i>i</i> -C ₃ H ₇ MgBr (1.0 mole) + C ₆ H ₅ MgBr (1.0 mole)	<i>i</i> -C ₃ H ₇ C ₆ H ₅ (13.5 g., 0.110 mole) + C ₆ H ₅ C ₆ H ₅ (42.0 g., 0.270 mole) + C ₆ H ₁₄ (1.0 g., 0.010 mole)	2
AgBr (1.0 mole)	<i>i</i> -C ₃ H ₇ MgBr (0.5 mole) + C ₆ H ₅ CH ₂ MgCl (0.5 mole)	<i>i</i> -C ₄ H ₉ C ₆ H ₅ (28.0 g., 0.210 mole) + C ₆ H ₅ CH ₂ CH ₂ C ₆ H ₅ (10.0 g., 0.055 mole)	2
AgBr (0.5 mole)	<i>n</i> -C ₄ H ₉ MgCl (0.5 mole C ₄ H ₉ Cl)	C ₆ H ₁₈ (10.8 g., 37.8%)	3
AgBr (1.0 mole)	<i>n</i> -C ₄ H ₉ MgBr (1.0 mole C ₄ H ₉ Br)	C ₆ H ₁₈ (24 g., 42%)	4
AgBr (0.5 mole)	<i>n</i> -C ₄ H ₉ MgBr (0.5 mole C ₄ H ₉ Br)	C ₆ H ₁₈ (18.4 g., 64.4%)	3
AgBr (2.0 moles)	<i>n</i> -C ₄ H ₉ MgBr (1.0 mole) + C ₆ H ₅ MgBr (1.0 mole)	<i>n</i> -C ₄ H ₉ C ₆ H ₅ (51.0 g., 0.381 mole) + C ₆ H ₅ C ₆ H ₅ (31.0 g., 0.200 mole) + C ₆ H ₁₈ (7.0 g., 0.062 mole)	2,3

*Ar = 2,5-(CH₃)₂C₆H₃, 1-C₁₀H₇, 4-C₆H₅OC₆H₄. Although no details are given, the reactions are said to be similar to that of C₆H₅MgBr.

TABLE V-I (Continued)

Metallic Halide	Grignard Reagent(s)	Product(s)	Ref.
AgBr (0.5 mole)	<i>n</i> -C ₄ H ₉ MgI (0.5 mole C ₄ H ₉ I)	C ₈ H ₁₈ (10.4 g., 36.4%)	3
AgBr (1.0 mole)	<i>i</i> -C ₄ H ₉ MgBr (1.0 mole)	C ₈ H ₁₈ (20.0 g., 37.5%) + gas	5
AgBr (1.0 mole)	<i>i</i> -C ₄ H ₉ MgBr (0.5 mole) + C ₆ H ₅ MgBr (0.5 mole)	<i>i</i> -C ₄ H ₉ C ₆ H ₅ (23.0 g., 0.170 mole) + C ₆ H ₅ C ₆ H ₅ (16.5 g., 0.107 mole) + C ₈ H ₁₈ (0.7 g., 0.006 mole)	2
AgBr (1.0 mole)	<i>s</i> -C ₄ H ₉ MgBr (1.0 mole)	C ₈ H ₁₈ (7.5 g., 13.0%) + gas	5
AgBr (2.0 moles)	<i>s</i> -C ₄ H ₉ MgBr (1.0 mole) + C ₆ H ₅ MgBr (1.0 mole)	<i>s</i> -C ₄ H ₉ C ₆ H ₅ (9.5 g., 0.070 mole) + C ₆ H ₅ C ₆ H ₅ (58.5 g., 0.370 mole) + C ₈ H ₁₈ (6.0 g., 0.050 mole)	2
AgBr (0.5 mole)	<i>t</i> -C ₄ H ₉ MgCl (0.5 mole)	C ₈ H ₁₈ (5.5 g., 19.4%)	6
AgBr (0.5 mole)	<i>t</i> -C ₄ H ₉ MgBr (0.25 mole) + C ₆ H ₅ MgBr (0.25 mole)	C ₆ H ₅ C ₆ H ₅ (13.0 g., 0.085 mole) + C ₆ H ₁₈ (2.0 g., 0.018 mole)	2
AgBr	C ₆ H ₅ MgBr	C ₆ H ₅ Ag (60%) $\xrightarrow{-18^\circ}$ C ₆ H ₅ C ₆ H ₅ + Ag	7
AgBr (1.0 mole)	C ₆ H ₅ MgBr (1.0 mole C ₆ H ₅ Br)	C ₆ H ₅ C ₆ H ₅ (51 g., 66%)	4
AgBr (0.5 mole)	C ₆ H ₅ MgBr (0.5 mole C ₆ H ₅ Br)	C ₆ H ₅ C ₆ H ₅ (25.0 g., 64.8%)	3
AgBr	C ₆ H ₅ MgBr + 4-CH ₃ OC ₆ H ₄ MgBr	C ₆ H ₅ C ₆ H ₅ (22.0-48.0%) + 4-CH ₃ OC ₆ H ₄ C ₆ H ₅ (4.7-8.2%) + 4-CH ₃ OC ₆ H ₄ C ₆ H ₄ -4-OCH ₃ (3.8-19.4%)	8
AgBr (0.4 mole)	<i>n</i> -C ₄ H ₉ C \equiv CMgBr (0.4 mole C ₆ H ₁₀)	<i>n</i> -C ₄ H ₉ C \equiv CAG (46 g., 62%)	10
AgBr (1.0 mole)	(CH ₂) ₅ CHMgBr (1.0 mole C ₆ H ₁₁ Br)	(CH ₂) ₅ CHCH(CH ₂) ₅ (25 g., 40%)	4
AgBr (0.25 mole)	<i>n</i> -C ₆ H ₁₃ MgBr (0.25 mole C ₆ H ₁₃ Br)	C ₁₂ H ₂₆ (15.3 g., 82.9%) + C ₆ H ₁₄ and C ₆ H ₁₂ (aggr. 1.2 g., <i>ca.</i> 6.7%)	9
AgBr (1.0 mole)	C ₆ H ₅ CH ₂ MgCl (1.0 mole C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CH ₂ C ₆ H ₅ (65 g., 71%)	4
AgBr (0.05 mole)	4-CH ₃ C ₆ H ₄ MgBr (0.05 mole C ₇ H ₇ Br)	4-CH ₃ C ₆ H ₄ C ₆ H ₄ -4-CH ₃ (3.3 g., 72%)	4
AgBr (0.35 mole)	4-CH ₃ OC ₆ H ₄ MgBr (0.35 mole C ₇ H ₇ BrO)	4-CH ₃ OC ₆ H ₄ C ₆ H ₄ -4-OCH ₃ (17.5 g., 48%)	4
CuI	C ₂ H ₅ MgI	C ₂ H ₄ + C ₂ H ₆ + Cu	7, 11

TABLE V-I (Continued)

<u>Metallic Halide</u>	<u>Grignard Reagent(s)</u>	<u>Product(s)</u>	<u>Ref.</u>
CuI	<i>n</i> -C ₃ H ₇ MgX	C ₃ H ₆ + C ₃ H ₈	11
CuI	C ₆ H ₅ MgI	C ₆ H ₅ Cu (60%)	7
CuX*	C ₂ H ₅ MgX'	C ₂ H ₄ + C ₂ H ₆	11
CuX*	<i>n</i> -C ₃ H ₇ MgX'	C ₃ H ₆ + C ₃ H ₈	11
CuCl ₂ (20.3 g.)	<i>i</i> -C ₅ H ₁₁ MgBr (22.7 g. C ₅ H ₁₁ Br)	C ₁₀ H ₂₂ (4-5 g., ca. 60%)	12
CuCl ₂	<i>t</i> -C ₄ H ₉ MgCl	No C ₆ H ₁₈	6
CuCl ₂ (27.0 g.)	C ₆ H ₅ MgBr (31.4 g. C ₆ H ₅)	C ₆ H ₅ C ₆ H ₅ (13.1 g., 90%)	12
CuCl ₂ (13.5 g.)	C ₆ H ₅ CH ₂ MgCl (12.6 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CH ₂ C ₆ H ₅ (7 g., 83.5%)	12
CuCl ₂ (51.3 g.)	2-CH ₃ C ₆ H ₄ MgBr (60.0 g.)	2-CH ₃ C ₆ H ₄ C ₆ H ₄ -2-CH ₃ (30%)	19
CuCl ₂ (27.0 g.)	4-CH ₃ C ₆ H ₄ MgBr (34.2 g. C ₇ H ₇ Br)	4-CH ₃ C ₆ H ₄ C ₆ H ₄ -4-CH ₃ (15.3 g., 84%)	12
CuCl ₂	C ₆ H ₅ CH=CHMgBr (1 equiv.)	C ₆ H ₅ CH=CHCH=CHC ₆ H ₅ (17.6%) [†]	13
CuCl ₂ (13.5 g.)	C ₆ H ₅ CH=CHMgBr (18.3 g. C ₈ H ₇ Br)	C ₆ H ₅ CH=CHCH=CHC ₆ H ₅ (3-4 g., 40-45%)	12
CuCl ₂ (13.5 g.)	1-C ₁₀ H ₇ MgBr (20.7 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ -1-C ₁₀ H ₇ (10.0 g., 80%)	12
CuBr ₂	C ₂ H ₅ MgX	C ₂ H ₄ + C ₂ H ₆	11
CuBr ₂	<i>n</i> -C ₃ H ₇ MgX	C ₃ H ₆ + C ₃ H ₈	11
CuBr ₂ (0.4 mole)	C ₆ H ₅ C≡CMgBr (0.4 mole C ₈ H ₆)	C ₆ H ₅ C≡CC≡CC ₆ H ₅ (29 g., 72%)	10
FeCl ₂	C ₂ H ₅ MgX	C ₂ H ₄ + C ₂ H ₆	11
FeCl ₂	<i>n</i> -C ₃ H ₇ MgX	C ₃ H ₆ + C ₃ H ₈	11
FeCl ₂ (0.01 mole)	C ₆ H ₅ MgI (0.03 mole)	C ₆ H ₅ C ₆ H ₅ (98%)	14
FeCl ₃	C ₂ H ₅ MgBr	C ₂ H ₄ + C ₂ H ₆	11
2 FeCl ₃	Alk-MgBr	Alk-Cl + 2 FeCl ₂ + MgBrCl	17

*X = Cl, Br, I, CN, CNS.

†A check experiment showed that dimer (Wurtz product) to the extent of 10 percent is formed in the preparation of the Grignard reagent.

TABLE V-I (Continued)

<u>Metallic Halide</u>	<u>Grignard Reagent(s)</u>	<u>Product(s)</u>	<u>Ref.</u>
2 FeCl ₃	2 C ₆ H ₅ MgBr	C ₆ H ₅ C ₆ H ₅ + 2 FeCl ₂	15
2 FeCl ₃	6 C ₆ H ₅ MgBr	3 C ₆ H ₅ C ₆ H ₅ + 2 Fe	15
FeCl ₃ (8.1 g.)	C ₆ H ₅ MgBr (23.8 g. C ₆ H ₅ Br)	C ₆ H ₅ C ₆ H ₅ (3.4 g.) + resin (2.4 g.) + FeCl ₂	16
FeCl ₃	C ₆ H ₅ MgBr	C ₆ H ₅ C ₆ H ₅	11
FeCl ₃	CH ₃ C ₆ H ₄ MgBr	CH ₃ C ₆ H ₄ C ₆ H ₄ CH ₃	11
CoCl ₂	C ₂ H ₅ MgX	C ₂ H ₄ + C ₂ H ₆	11
CoCl ₂	<i>n</i> -C ₃ H ₇ MgBr	C ₃ H ₆ + C ₃ H ₈	11
CoCl ₂ (0.03 mole)	C ₆ H ₅ MgBr (0.11 mole)	C ₆ H ₅ C ₆ H ₅ (64%)	18
CoBr ₂ (0.01 mole)	C ₆ H ₅ MgI (0.03 mole)	C ₆ H ₅ C ₆ H ₅ (98%)	14
CoBr ₂	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	[2,4,6-(CH ₃) ₃ C ₆ H ₂ —] ₂ (20%)	14
NiCl ₂	C ₂ H ₅ MgX	C ₂ H ₄ + C ₂ H ₆	11
NiCl ₂	<i>n</i> -C ₃ H ₇ MgX	C ₃ H ₆ + C ₃ H ₈	11
NiBr ₂ (0.03 mole)	C ₆ H ₅ MgI (0.095 mole)	C ₆ H ₅ C ₆ H ₅ (100%)	14

REFERENCES FOR TABLE V-I

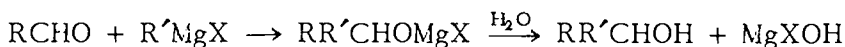
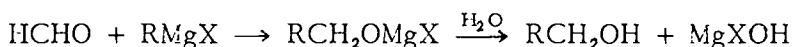
- (1) Krause and Wendt, *Ber.*, 56B, 2064-6 (1923).
- (2) Joseph and Gardner, *J. Org. Chem.*, 5, 61-7 (1940).
- (3) Bickley and Gardner, *J. Org. Chem.*, 5, 126-32 (1940).
- (4) Gardner and Borgstrom, *J. Am. Chem. Soc.*, 51, 3375-7 (1929).
- (5) Gardner and Joseph, *J. Am. Chem. Soc.*, 61, 2551-2 (1939).
- (6) Whitmore, Stehman, and Herdon, *J. Am. Chem. Soc.*, 55, 3807-9 (1933).
- (7) Reich, *Compt. rend.*, 177, 322-4 (1923); *Chem. Zentr.*, 1923,III, 1010.
- (8) Gardner, Joseph, and Gollub, *J. Am. Chem. Soc.*, 59, 2583-4 (1939).
- (9) Gardner and Snyder, *J. Am. Chem. Soc.*, 62, 2879-80 (1940).
- (10) Danehy and Nieuwland, *J. Am. Chem. Soc.*, 58, 1609-10 (1936).
- (11) Kondyrew and Fomin, *J. Russ. Phys.-Chem. Soc.*, 47, 190-8 (1915); *Chem. Zentr.*, 1916,I, 832.
- (12) Sakellarios and Kyrimis, *Ber.*, 57B, 322-6 (1924).
- (13) Gilman and Parker, *J. Am. Chem. Soc.*, 46, 2823-7 (1924).
- (14) Gilman and Lichtenwalter, *J. Am. Chem. Soc.*, 61, 957-9 (1939).
- (15) Champetier, *Bull. soc. chim.*, [4], 47, 1131-7 (1930).
- (16) Bennett and Turner, *J. Chem. Soc.*, 105, 1057-62 (1914).
- (17) Oddo, *Gazz. chim. ital.*, 44,II, 268-78 (1914); *Chem. Abstr.*, 9, 795 (1915); *Chem. Zentr.*, 1915,I, 743.
- (18) Kharasch and Fields, *J. Am. Chem. Soc.*, 63, 2316-20 (1941).
- (19) Turner, *J. Proc. Royal Soc. N.S. Wales*, 54, 37-9 (1920); *Chem. Abstr.*, 15, 669 (1921).

CHAPTER VI

Reactions of Grignard Reagents with Aldehydes, Ketones, and Ketenes

THE "NORMAL" ADDITION REACTIONS

Probably in part for historical reasons, and in part because of their general utility as preparative methods, the addition reactions at the carbonyl double bond have come to be regarded as the "normal" reactions of Grignard reagents with aldehydes and ketones. These additions are polar in the sense that the cationoid (electrophilic) portion of the Grignard reagent becomes attached to the relatively negative oxygen atom, whereas the anionoid (nucleophilic, electrodotic) portion of the reagent becomes attached to the relatively positive carbon atom. Although Grignard reagent solutions are now known to be much more complex systems than the simple formulations originally employed by Grignard might seem to imply (see Chapter IV, Constitution and Dissociation of Grignard Reagents), those simple formulations are altogether adequate to describe their stoichiometrical behavior.



Although these additions are polar, that they are not necessarily ionic in the sense that ionic *dissociation* of the Grignard reagent is a prerequisite to their occurrence is suggested by the fact that they may be conducted in such inert, nonionizing solvents as benzene and toluene.

Of the details of reaction mechanism, little can be said with assurance. Various investigators, among them Straus¹, Grignard², von Braun *et al.*³, Meisenheimer⁴, and Hess *et al.*⁵, have suggested that the first step in the

¹Straus, *Ann.*, 393, 235-337 (1912) (footnote, p. 241).

²Grignard, *Bull. soc. chim.*, [4], 13, Conference, I-XXXVII (1913).

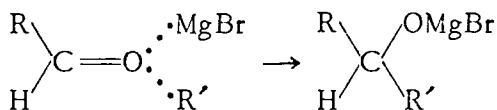
³(a) von Braun, Heider, and Miller, *Ber.*, 50, 1637-51 (1917); (b) von Braun and Kirschbaum, *ibid.*, 52B, 1725-30 (1919).

⁴Meisenheimer and Casper, *Ber.*, 54B, 1655-65 (1921); Meisenheimer, *Ann.*, 442, 180-210 (1925).

⁵Hess and Rheinboldt, *Ber.*, 54B, 2043-55 (1921); Hess and Wustrow, *Ann.*, 437, 256-73 (1924); Rheinboldt and Roleff, *J. prakt. Chem.*, [2], 109, 175-90 (1925).

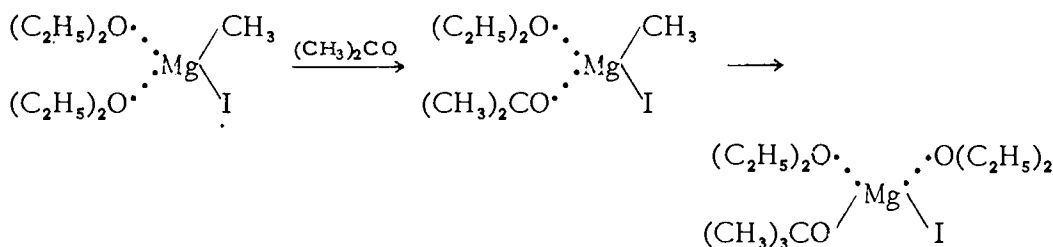
reaction of a Grignard reagent with a carbonyl compound is the formation of a complex of one sort or another.

von Braun's complex, like Grignard's, is patterned after the ether oxonium complex of Grignard⁶, and a subsequent rearrangement to the alkoxide form in the case of addition reactions is assumed.

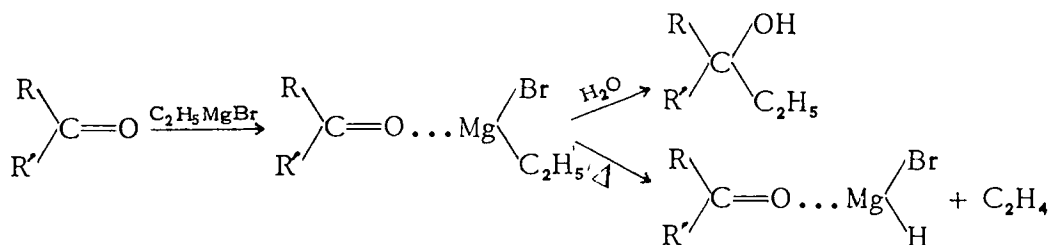


Neither concept can be satisfactorily represented in electronic notation.

Meisenheimer's complex is of the Werner type with a coördination number of four for magnesium; rearrangement in the course of addition is postulated.



Hess's complex is of a type not very clearly defined, and no rearrangement prior to hydrolysis is postulated, save in the case of reduction.



On the whole, Meisenheimer's description of the complex accords best with modern chemical concepts and with the known properties of Grignard reagents, although there is now good reason to doubt that addition is effected by so simple a process as monomolecular complex rearrangement.

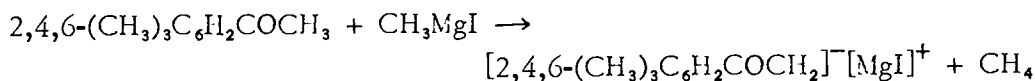
Klages⁷ believed that he had isolated such a complex when he added acetomesitylene [2,4,6-(CH₃)₃C₆H₂COCH₃] to two equivalents of ethereal ethylmagnesium iodide and obtained a white crystalline precipitate which gave an elementary analysis which he accepted as consistent with the formulation (CH₃)₃C₆H₂COCH₃·C₂H₅MgI·(C₂H₅)₂O. Even after five hours heating at 100°, treatment of the precipitate with water regenerated acetomesitylene. However, it has since been shown by Kohler *et al.*⁸ that treatment of a xylene solution of acetomesitylene with excess methyl-

⁶Grignard, *Bull. soc., chim.*, [3], 29, 944-8 (1903).

⁷Klages, *Ber.*, 35, 2633-46 (1902).

⁸Kohler, Stone, and Fuson, *J. Am. Chem. Soc.*, 49, 3181-8 (1927).

magnesium iodide in isoamyl ether solution results in the evolution of methane and the quantitative formation of an enolate, according to the equation:



Klages' product, therefore, is almost certainly that suggested by Kohler and Baltzly⁹, $[(\text{CH}_3)_3\text{C}_6\text{H}_2\text{COCH}_2]^-[\text{MgI}]^+ \cdot (\text{C}_2\text{H}_5)_2\text{O}$, probably contaminated with a little excess ether.

Indirect evidence of intermediate Grignard reagent complex formation with camphor (1,7,7-trimethylbicyclo[2.2.1]heptan-2-one), a relatively unreactive cyclic ketone, is reported by Bredt-Savelsburg¹⁰, who has observed that camphor does not sublime from Grignard reagent mixtures as it does from ordinary mechanical mixtures. That this phenomenon is not attributable to enolate formation is indicated by the extreme slowness with which camphor is enolized by Grignard reagents (see Enolate Formation by Grignard Reagents, p. 166).

More positive evidence of Grignard reagent-carbonyl group complex formation involves the relatively unreactive non-enolizable cyclic ketone fenchone (1,3,3-trimethylbicyclo[2.2.1]heptan-2-one). Leroide¹¹ reports that this ketone combines with phenyl-, o-tolyl-, and p-tolylmagnesium bromides to give products insoluble in ether-toluene solution. By prolonged heating in large quantities of solvent these are slowly converted to the corresponding alcoholates. A 7 percent yield of the phenyl tertiary alcohol was obtained in this way. The more reactive¹² benzylmagnesium chloride formed the alcoholate directly to give a 45 percent yield of the tertiary alcohol.

Nesmeyanov and Sazanova¹³ have confirmed the observation that phenylmagnesium bromide forms an ether-insoluble product with fenchone. According to them, this product gives no Gilman color test with Michler's ketone (see Chapter III, Estimation and Detection of Grignard Reagents), an indication that the complex is remarkably stable. Partial analysis revealed a magnesium-bromide ratio of 1.0:1.4, an indication that the MgBr_2 and $\text{C}_6\text{H}_5\text{MgBr}$ complexes are less soluble than the $(\text{C}_6\text{H}_5)_2\text{Mg}$ complex (see Chapter IV, Constitution and Dissociation of Grignard Reagents). This might account for their failure to isolate benzene when fenchone is regenerated by hydrolysis of the precipitate.

⁹Kohler and Baltzly, *J. Am. Chem. Soc.*, 54, 4015-26 (1932).

¹⁰Bredt-Savelsburg, *J. prakt. Chem.*, [2], 107, 65-85 (1924).

¹¹Leroide, *Compt. rend.*, 148, 1611-3 (1909); *Chem. Zentr.*, 1909, II, 358.

¹²Concerning relative reactivities of Grignard reagents toward carbonyl groups see: Kharasch and Weinhouse, *J. Org. Chem.*, 1, 209-30 (1936).

¹³Nesmeyanov and Sazanova, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1941, 499-519; *Chem. Abstr.*, 37, 2723 (1943).

Kohler¹⁴ reports that in cold ethereal solution ethylmagnesium bromide forms with diphenylbenzalacetophenone $[\text{C}_6\text{H}_5\text{COC}(\text{C}_6\text{H}_5)=\text{C}(\text{C}_6\text{H}_5)_2]$ a combination that is in part precipitated. Upon hydrolysis the ketone is recovered quantitatively. Obviously, enolization is not involved. Prolonged boiling of the ethereal suspension brings about true reaction which results in at least 30 percent yield of the carbinol (or its dehydration product). According to Kohler and Nygaard¹⁵ neither methylmagnesium iodide nor phenylmagnesium bromide react with diphenylbenzalacetophenone in ethereal solution, even under prolonged reflux, but reaction can be brought about by operating at somewhat higher temperatures in benzene.

von Braun *et al.*¹⁶ report that, with acetone, butanone, and acetophenone, the Grignard reagent prepared from *N*-methyl-*N*- β -bromoethylaniline forms ether-insoluble complexes from which the ketones may be recovered by hydrolysis. With the more reactive butyraldehyde, however, normal reaction takes place.

Complexes of methylmagnesium iodide with acetobromoglucose ($\text{C}_{14}\text{H}_{19}\text{O}_9\text{Br} \cdot 2 \text{CH}_3\text{MgI}$), pentaacetylglucose ($\text{C}_{16}\text{H}_{22}\text{O}_{11} \cdot 2 \text{CH}_3\text{MgI}$), tetraacetylglucose ($\text{C}_{14}\text{H}_{20}\text{O}_{10} \cdot 2 \text{CH}_3\text{MgI}$), and tetraacetyl α -methyl glucoside ($\text{C}_{15}\text{H}_{22}\text{O}_{10} \cdot 2 \text{CH}_3\text{MgI}$) have also been reported by Fischer and Hess¹⁷.

Pfeiffer and Blank¹⁸ (who, incidentally, accepted Klages' acetomesitylene "complex" at face value) have advanced the hypothesis that alcoholate formation is effected, not by monomolecular rearrangement of the Grignard reagent-carbonyl group complex, but by interaction of the complex with a second molecule of Grignard reagent. They reported that the addition of one equivalent of an ethereal ethylmagnesium bromide solution to an ethereal benzophenone solution (concentrations not stated) gave rise to a "dirty" white precipitate which quickly coalesced into an oily, ether-insoluble subsident layer. The oily product was regarded as unsuitable for analysis but was found to regenerate most of the benzophenone originally present when treated with water. When the experiment was repeated with two or three equivalents of ethylmagnesium bromide the alcoholate $[\text{C}_2\text{H}_5(\text{C}_6\text{H}_5)_2\text{COMgBr}]$ was formed.

For the remainder of their study Pfeiffer and Blank unfortunately chose ketones that could yield only equivocal results, namely: *p*-aminobenzophenone, *p*-dimethylaminobenzophenone, and Michler's ketone [*p,p'*-bis(dimethylamino)benzophenone]. It is well-known that most primary aromatic amines behave toward Grignard reagents at room (or lower) temperature as though they contained one "active" hydrogen atom (see

¹⁴Kohler, *Am. Chem. J.*, 38, 511-61 (1907).

¹⁵Kohler and Nygaard, *J. Am. Chem. Soc.*, 52, 4128-39 (1936).

¹⁶von Braun, Heider, and Miller, *Ber.*, 50, 1637-51 (1917).

¹⁷Fischer and Hess, *Ber.*, 45, 912-5 (1912).

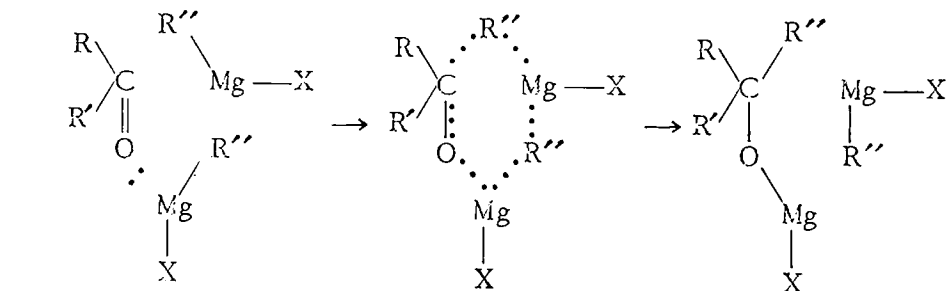
¹⁸Pfeiffer and Blank, *J. prakt. Chem.*, [2], 153, 242-56 (1939).

Chapter XVIII) and that tertiary amines form Grignard reagent complexes which are, in general, more stable and less ether-soluble than the corresponding "etherates" (see Chapter II, Preparation of Grignard Reagents in Solvents Other than Ethyl Ether).

The validity of the benzophenone experiment of Pfeiffer and Blank (*loc. cit.*¹⁸) has been questioned by Nesmeyanov and Sazanova (*loc. cit.*¹³), who state that the precipitate formed when an ethereal solution of benzophenone is added dropwise to one equivalent of ethereal ethylmagnesium bromide is the alcoholate. However, the differences in the two experimental techniques employed are altogether adequate to account for the differences in observed results. If the reaction scheme proposed by Pfeiffer and Blank is indeed the correct one, use of the "normal" order of reactant addition (which insures that the major portion of the reaction take place in the presence of an excess of Grignard reagent) should lead to alcoholate formation.

The reaction mechanism proposed by Pfeiffer and Blank is also the one favored by Swain¹⁹, who has studied the kinetics of the nitrile-Grignard reagent reaction (see Chapter X, Reactions of Grignard Reagents with Nitriles and Other Cyano Compounds). The second-order nature of the latter reaction, considered in conjunction with the relative reactivities of nitriles toward phenylmagnesium bromide²⁰ and the relative reactivities of various Grignard reagents with benzonitrile, and with the relative migration tendencies of organic radicals in the pinacol rearrangement, leads Swain to conclude that the rate-determining step is probably an intramolecular rearrangement of a Werner complex. In the ketone reactions the radical order of reactivity of Grignard reagents toward benzophenone²¹ is the reverse of the order of reactivity toward benzonitrile. The reactions must therefore have different mechanisms, and, since the direct reaction of ketone with Grignard reagent seems to be excluded, the reaction of Grignard reagent with activated complex appears most probable.

It may be remarked in passing (though entirely without prejudice) that this is one of several instances in which the concept of a quasi six-membered ring may be invoked to suggest for Grignard reactions a mechanism consistent with the observed facts.



¹⁹Swain, *J. Am. Chem. Soc.*, 69, 2396-9 (1947).

²⁰Gilman and Lichtenwalter, *Rec. trav. chim.*, 55, 588-90 (1936).

²¹Kharasch and Weinhouse, *J. Org. Chem.*, 1, 209-30 (1936).

PREPARATIVE PROCEDURES

Grignard's²² method of conducting reactions between organomagnesium halides and aldehydes, ketones, or esters was essentially the same in all cases. To one equivalent of ethereal Grignard reagent solution in a water-cooled flask, equipped with a reflux condenser, was added dropwise one molecular equivalent of aldehyde or ketone, or one-half molecular equivalent of ester, dissolved in its own volume of anhydrous ethyl ether. If the product proved to be soluble in ether, reaction was then completed by several hours gentle reflux on a water-bath. If the product proved to be a crystalline precipitate or a viscous subsident layer, Grignard preferred, rather than risk local superheating, to allow the reaction mixture to stand for a day at laboratory temperature.

The product was then hydrolyzed by portionwise addition of cracked ice to the reaction mixture, and precipitated magnesium hydroxide was dissolved by the addition of a little hydrochloric acid or a dilute solution of acetic acid. The ethereal layer was then separated, washed successively with sodium bicarbonate and sodium bisulfite solutions, and eventually distilled, with the aid of reduced pressure if necessary. In cases in which the alcoholic product was appreciably soluble in water, the aqueous layer was subjected to steam distillation, and the distillate was "salted" with potassium carbonate.

For the more readily reactive ether-soluble carbonyl compounds, reacting with the chosen Grignard reagent to yield relatively stable (as regards dehydration) alcohols, Grignard's procedure requires little modification. Efficient mechanical stirring during the addition operation, and, in cases in which the product is ether-insoluble, throughout the entire reaction period is desirable. Ice or ice-salt cooling is both more efficient and more convenient than cooling with running water.

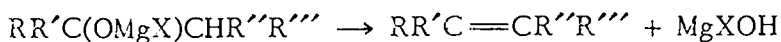
If the carbonyl compound is both ether-insoluble and relatively unreactive, it may be added to the Grignard reagent solution dropwise (if a liquid) or portionwise in the form of a fine powder (if a solid). For the sake of convenience, solids may be powdered and suspended in ether, or, better, dissolved in some suitable solvent such as benzene, toluene, or xylene. If the carbonyl compound, though ether-insoluble, is relatively reactive, suspension or solution (preferably the latter) is indicated.

For very unreactive carbonyl compounds, it is often desirable, and sometimes necessary, either to add to the ethereal solution or suspension a higher-boiling solvent (e.g., benzene, toluene, or a high-boiling ether) or to replace the ethyl ether in whole or in part with such a solvent. This is usually best accomplished by employing the high-boiling liquid as a solvent or suspension medium for the addition of the carbonyl compound

²²Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).

and then, if desirable, removing part or all of the ethyl ether by distillation. In cases where it is necessary to resort to such tactics, however, it must be anticipated that the isolable product may be an olefin (the result of dehydration of the primary reaction product), especially if the primary product is the halomagnesium alcoholate of a readily dehydrated alcohol.

While it seems highly probable that some "dehydrations" take place prior to hydrolysis by a thermally-induced decomposition of the type



many are unquestionably attributable to the method of recovery of the product.

Other considerations permitting, dehydration may be prevented or minimized by: (1) conducting the Grignard reaction at a relatively low temperature; (2) avoiding excess acidity in the hydrolysis operation (as by employing iced saturated ammonium chloride solution as a hydrolyzing agent); (3) removing all traces of acid from the hydrolysis product (as by thorough washing with sodium bicarbonate solution); and (4) conducting the final distillation at very low pressure (preferably a fraction of a millimeter of mercury).

Because there is usually no objection to the presence of an excess of Grignard reagent, whereas the presence of an excess of carbonyl compound may be disadvantageous,* the "normal" order of addition (*i.e.*, the addition of carbonyl compound to the Grignard reagent) is almost invariably employed for preparative purposes in the case of aldehydes and ketones. When the concentration of the Grignard solution is known through analysis, a slight measured excess is usually employed. Because Grignard reagent yields are always somewhat, and often considerably, less than quantitative, due allowance must be made for this fact if it is known or suspected that an excess of carbonyl compound may prove disadvantageous.

Formaldehyde (generated by thermal depolymerization of one of its polymers) may be bubbled into a Grignard reagent solution or led over its surface (preferably in a stream of dry nitrogen). Alternatively, the solid polymer may be added to the Grignard reagent solution, and the mixture may then be submitted to prolonged reflux.

Citations to a few illustrative preparations described in some detail in the literature are assembled in Table VI-I. Others may be located by reference to the appropriate reaction tabulations.

*As, for example, in the case of the oxidation of the Grignard reaction product by benzaldehyde (see Alkoxide Reduction, p. 158).

TABLE VI-I
SOME ILLUSTRATIVE PREPARATIVE REACTIONS OF GRIGNARD REAGENTS WITH ALDEHYDES AND KETONES
(Yield refers to "normal" product.)

Reactants	Mode of Add'n	Reaction Time	Hydrolytic Agent	Yield (%)	Ref.
HCHO (from 38 g. paraform) + <i>s</i> -C ₄ H ₉ MgBr (150 g. C ₄ H ₉ Br)	Gas + N ₂ into ice-salt-cooled G.r.	HCHO absorb'n + 5 min. (odor)	Ice	67	1
HCHO (from 50 g. paraform) + (CH ₂) ₅ CHMgCl (118.5 g. C ₆ H ₁₁ Cl)	Gas + N ₂ over G.r. at room temp.	Ca. 1.75 hr.	Ice + 30% H ₂ SO ₄	64-69	2
"Trioxymethylene" (30 g.) + <i>n</i> -C ₁₈ H ₃₇ MgCl (144.4 g. C ₁₈ H ₃₇ Cl)	Single add'n solid to G.r.	6-8 hrs. reflux	30% H ₂ SO ₄ (ice-cooling)	59	3
Polyoxymethylene (1 equiv) + <i>n</i> -C ₅ H ₁₁ MgBr (in <i>i</i> -Am ₂ O)	Single add'n solid to cooled G.r.	1 hr. at 150°	Ice + aqu. HCl	47	4
CH ₃ CHO (44 g.) + C ₂ H ₅ MgBr (115 g. C ₂ H ₅ Br)	Grad'l add'n Et ₂ O-RCHO to ice-cooled G.r.	Add'n time + 0.5 hr.	H ₂ O + dil. aqu. HCl	80	5
CH ₃ CHO (from 30 g. paraldehyde) + C ₂ H ₅ MgBr (680 g. C ₂ H ₅ Br)	Gas + N ₂ into G.r.	12 hrs.	Ice + NH ₄ Cl	67	1
CH ₃ CH=CHCHO + <i>n</i> -C ₃ H ₇ MgBr ("large excess")	Add'n RCHO to G.r. at -28 to -22°	Overnight at 25°	Iced aqu. H ₂ SO ₄	78	6
C ₆ H ₅ CHO (15.9 g.) + (CH ₃) ₂ N(CH ₂) ₃ MgCl (30 g. C ₅ H ₁₂ ClN)	Portionwise add'n Et ₂ O-RCHO to G.r.	12 hrs. reflux	Ice + aqu. HCl	70	7
4-CH ₃ OC ₆ H ₄ CHO (28 g.) + C ₆ H ₅ MgBr (40 g. C ₆ H ₅ Br)	Dropwise add'n RCHO to ice-cooled G.r.	24 hrs. at 0°	Cold dil. aqu. HAc	90	8

TABLE VI-I (Continued)

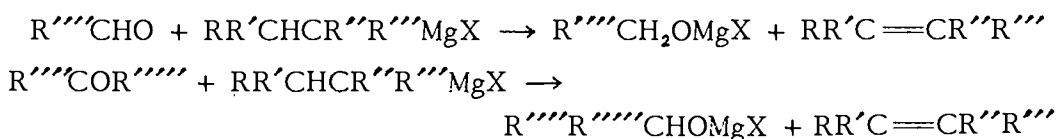
Reactants	Mode of Add'n	Reaction Time	Hydrolytic Agent	Yield (%)	Ref.
9-Anthraldehyde (30 g.) + CH_3MgI (21.5 g. CH_3I)	Add'n $\text{C}_6\text{H}_5\text{-RCHO}$ to G.r.	0.5 hr. reflux	Aqu. NH_4Cl	92	9
$(\text{CH}_3)_2\text{CO}$ (6 moles) + $n\text{-C}_4\text{H}_9\text{MgBr}$ (6.5 moles $\text{C}_4\text{H}_9\text{Br}$)	Slow add'n $\text{Et}_2\text{O-}$ R_2CO to G.r.	Overnight at room temp.	H_2O + ice + 10% aqu. HCl	92	10
$\text{HON=CHCOC}_6\text{H}_5$ (15 g.) + $\text{C}_6\text{H}_5\text{MgBr}$ (80 g. $\text{C}_6\text{H}_5\text{Br}$)	Portionwise add'n powdered RCOR' to G.r.	1 hr. reflux	Ice + 10% aqu. H_2SO_4	75	11
$(\text{C}_6\text{H}_5)_2\text{CO}$ (18.2 g.) + $\text{H}_2\text{C=CHCH}_2\text{MgBr}$ (100 ml. 1.32 N)	Dropwise add'n $\text{C}_6\text{H}_5\text{-R}_2\text{CO}$ to G.r. at $10\text{-}20^\circ$	Add'n time	10% aqu. H_2SO_4	72	12
$\text{C}_6\text{H}_5\text{CO-1-C}_{10}\text{H}_7$ (0.10 mole) + $n\text{-C}_3\text{H}_7\text{MgBr}$ (0.12 mole $\text{C}_3\text{H}_7\text{Br}$)	Portionwise add'n $\text{C}_6\text{H}_5\text{-RCOR}'$ to ice-cooled G.r.	24 hrs.	Ice + NH_4Cl	65	13
2-Methylcyclohexanone (6 moles) + CH_3MgI (7 moles)	Slow add'n $\text{Et}_2\text{O-}$ RCOR' to ice- cooled G.r.	Add'n time (8 hrs.) + warming to room temp.	Ice + aqu. HCl	67	14
7-Methyl- α -tetralone + $i\text{-C}_3\text{H}_7\text{MgBr}$ (1.25 equiv. Mg)	Slow add'n $\text{Et}_2\text{O-}$ RCOR' to ice- cooled G.r.	Warming to room temp.; 5-10 min. reflux	Ice + NH_4Cl	70	15

REFERENCES FOR TABLE VI-I.

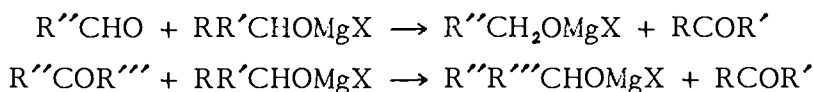
- (1) Wood and Scarf, *J. Soc. Chem. Ind.*, 42, 13-15T (1923).
- (2) Gilman and Catlin, *Organic Syntheses*, Coll. Vol. I, 2nd ed., 188-90 (1941).
- (3) Turkiewicz, *Ber.*, 72B, 1060-3 (1939).
- (4) Veibel, Lundqvist, Anderson, and Frederiksen, *Bull. soc. chim.*, [5], 6, 990-8 (1939).
- (5) Clarke, *J. Am. Chem. Soc.*, 30, 1144-52 (1908).
- (6) Stevens, *J. Am. Chem. Soc.*, 57, 1112-7 (1935).
- (7) Marxer, *Helv. Chim. Acta*, 24, 209-15E (1941).
- (8) Bachmann, *J. Am. Chem. Soc.*, 55, 2135-9 (1933).
- (9) Fieser and Hartwell, *J. Am. Chem. Soc.*, 60, 2555-9 (1938).
- (10) Edgar, Calingaert, and Marker, *J. Am. Chem. Soc.*, 51, 1483-91 (1929).
- (11) Orékhoff and Tiffeneau, *Bull. soc. chim.*, [4], 41, 839-43 (1927).
- (12) Kharasch and Weinhouse, *J. Org. Chem.*, 1, 209-30 (1934).
- (13) Blicke and Powers, *J. Am. Chem. Soc.*, 51, 3378-83 (1929).
- (14) Signaigo and Cramer, *J. Am. Chem. Soc.*, 55, 3326-32 (1933).
- (15) Barnett and Sanders, *J. Chem. Soc.*, 1933, 434-7.

GRIGNARD REDUCTIONS OF ALDEHYDES AND KETONES

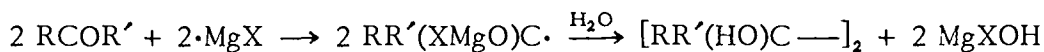
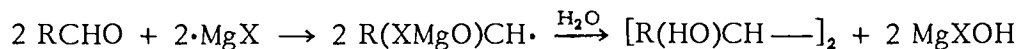
Three types of Grignard reduction of carbonyl compounds have been observed. In the first, a Grignard reagent of the type $RR'CHCR''R'''MgX$ (in which, R, R', R'', and R''' may be H) serves as the reducing agent:



In the second, an alkoxide of the type $RR'CHOMgX$ is the reducing agent:



In the third, reduction is effected by magnesian halide ($\cdot MgBr$ or $\cdot MgI$):



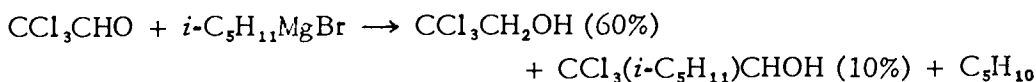
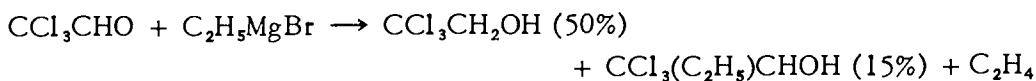
The first two are hydrogenation reductions; the third involves electron transfer only.

Reduction by the Grignard reagent. The true Grignard reagent reduction was first observed by Grignard himself, and was reported in his doctoral dissertation and in his classical paper on the preparation and reactions of organomagnesium halides²³. From the reaction between isoamylmagnesium bromide and benzaldehyde, he obtained as byproducts, in addition to a 56 percent yield of the expected secondary alcohol, small amounts of benzyl alcohol and biisoamyl. (The biisoamyl was undoubtedly the

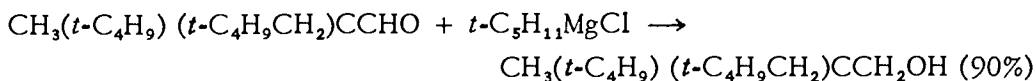
²³Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).

product of a Wurtz side-reaction occurring during the preparation of the Grignard reagent.)

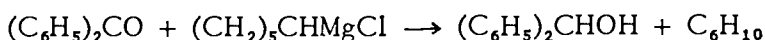
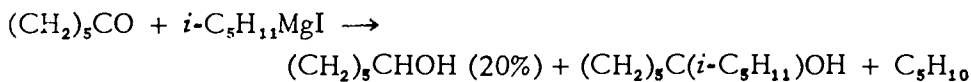
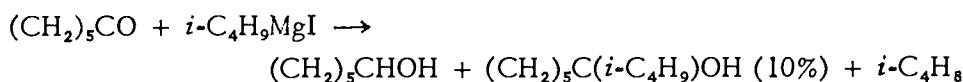
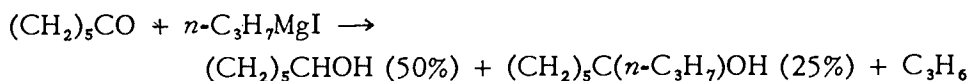
Similar reductions of chloral were observed by Iotsitch²⁴, who also noted the simultaneous evolution of olefin.*



Whitmore *et al.*²⁵ have reported a nearly quantitative aldehyde reduction by *t*-amylmagnesium chloride.



The analogous reduction of ketones, with simultaneous olefin liberation, was observed by Sabatier and Mailhe²⁶.



²⁴Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 36, 443-6 (1904); *Bull. soc. chim.*, [3], 34, 329 (1905). See also: Hébert, *Bull. soc. chim.*, [4], 27, 45-55 (1920); Dean and Wolf, *J. Am. Chem. Soc.*, 58, 332-3 (1936); Kharasch, Kleiger, Martin, and Mayo, *ibid.*, 63, 2305-7 (1941); Gilman and Abbot, *J. Org. Chem.*, 8, 224-9 (1943); Floutz, *J. Am. Chem. Soc.*, 65, 2255 (1943).

*Too much theoretical significance should not be ascribed to the quantitative aspects of early studies described here, or in analogous discussions hereafter. Investigations at the University of Chicago [e.g., Kharasch, Kleiger, and Mayo, *J. Am. Chem. Soc.*, 63, 2305-7 (1941)] indicate that quantitative, and in some cases qualitative, relationships may be materially affected by relatively small quantities of metallic impurities present in the magnesium employed for the preparation of the Grignard reagent.

²⁵Whitmore, Whitaker, Mosher, Breivik, Wheeler, Miner, Sutherland, Wagner, Clapper, Lewis, Lux, and Popkin, *J. Am. Chem. Soc.*, 63, 643-54 (1941).

²⁶Sabatier and Mailhe, (a) *Compt. rend.*, 139, 343-6 (1904); *J. Chem. Soc.*, 86, 1, 809 (1904); *Chem. Zentr.*, 1904, II, 704; (b) *Ann. chim.*, [8], 10, 527-74 (1907).

Early observations were summarized by Sabatier and Mailhe²⁷ essentially as follows. "Secondary reactions of this type occur as a rule only to a slight extent when the Grignard reaction is applied to aliphatic or aromatic aldehydes, chloral being the most notable exception. With ketones, and especially cyclic ketones, on the contrary, the secondary reaction assumes greater importance. The nature of the alkyl group in the alkylmagnesium halide used also exerts some influence on the extent to which the secondary reaction takes place; thus isobutyl favors its occurrence, whilst primary alkyl groups as a rule show this tendency to a much less extent, and aromatic groups do not exhibit it at all. Magnesium haloid derivatives of secondary alkyl groups always furnish the secondary reaction to a greater or less extent."

Hess and Wustrow²⁸ reported the isolation of the primary addition products of ethylmagnesium bromide, isobutylmagnesium bromide, and isobutylmagnesium chloride with cinnamaldehyde, and stated that on heating, they lost in weight an amount corresponding to one equivalent of olefin. Meisenheimer²⁹ was unable to confirm these results, and also called attention to the fact that Hess and Wustrow had actually isolated from the reaction of isobutylmagnesium chloride with cinnamaldehyde only about 8.5 percent of the amount of isobutylene bromide corresponding to the amount of cinnamic alcohol obtained. In his own experiments on the reduction of benzaldehyde with ethylmagnesium and isobutylmagnesium bromides, Meisenheimer did not succeed in isolating the theoretically equivalent quantities of olefin. Blicke and Powers³⁰ isolated approximately 23 percent of the total amount of alkyl radical as propylene bromide from a reaction of *n*-propylmagnesium bromide with benzophenone which resulted in 50 percent reduction of the ketone to benzhydrol. Using a technique better adapted to the quantitative isolation of products, Noller *et al.*³¹, were able to show that in the reaction of isobutylmagnesium bromide with benzophenone, the amount of isobutylene evolved corresponds exactly to the amount of benzhydrol produced. They further demonstrated that not more than 0.1 percent of the hydrocarbon evolved can be isobutane.

Whitmore and George³² have also shown that in the reaction between isopropylmagnesium bromide and diisopropyl ketone, within reasonable limits of experimental error, the amount of propylene evolved corresponds to the amount of secondary alcohol produced, and the amount of propane to the amount of enolization.

²⁷Sabatier and Mailhe, *Compt. rend.*, 141, 298-301 (1905); *J. Chem. Soc.*, 88, 1, 706 (1905).

²⁸Hess and Wustrow, *Ann.*, 437, 256-73 (1924).

²⁹Meisenheimer, *Ann.*, 442, 180-210 (1925).

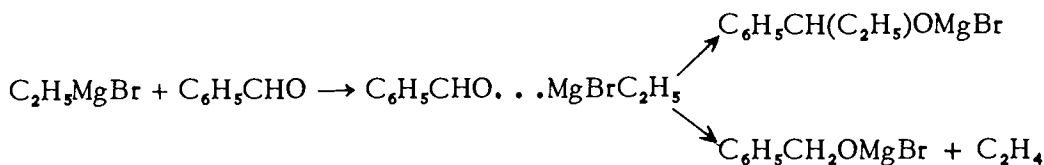
³⁰Blicke and Powers, *J. Am. Chem. Soc.*, 51, 3378-83 (1929).

³¹Noller, Grebe, and Knox, *J. Am. Chem. Soc.*, 54, 4690-6 (1932).

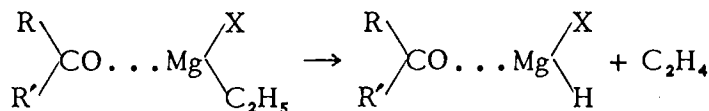
³²Whitmore and George, *J. Am. Chem. Soc.*, 64, 1239-42 (1942).

It now appears fairly evident that failure to isolate equivalent quantities of reduction product and olefin in reactions of this type is attributable either to: (1) inadequate method, (2) faulty technique, or (3) especially in the case of aldehydes, to the presence of excess carbonyl compound, leading to some reduction of the alkoxide type (*q. v.*).

Meisenheimer's formulation of the reactions between benzaldehyde and ethylmagnesium bromide is, of course, little more than a record of the observed products.



The somewhat similar formulation of Hess *et al.*³³ for aldehydes, and of Rheinboldt and Roleff³⁴ for ketones includes a concept that might or might not be significant.



About the only direct experimental evidence advanced in support of an intermediate complex of the kind suggested by Hess and Rheinboldt is the observation of Noller *et al.* (*loc. cit.*³¹) that when isobutylmagnesium bromide and benzophenone react in *n*-butyl ether solution there is immediate evolution of isobutylene, but no permanent precipitation of $(\text{C}_6\text{H}_5)_2\text{CHOMgBr}$, notwithstanding the fact that the alkoxide is soluble in *n*-butyl ether to the extent of only 0.006 g. per ml. That the solubility of the intermediate is not a supersaturation effect was shown by addition of solid $(\text{C}_6\text{H}_5)_2\text{CHOMgBr}$ to the solution. However, the possibility of formation of a relatively soluble complex of $(\text{C}_6\text{H}_5)_2\text{CHOMgBr}$ with excess Grignard reagent or with magnesium bromide is not precluded.³⁵ There is also the possibility that the reduction product is largely in the form of $[(\text{C}_6\text{H}_5)_2\text{CHO}]_2\text{Mg}$, which is relatively ether-soluble.³⁶

Whether or not such compounds as halomagnesium hydrides actually exist, either independently or as complex components, remains an open question, although bromomagnesium hydride (HMgBr) as a reducing agent has been made the subject of patent claims.³⁷

³³Hess and Rheinboldt, *Ber.*, 54B, 2043-55 (1921); Hess and Wustrow, (*loc. cit.*²⁸).

³⁴Rheinboldt and Roleff, *J. prakt. Chem.*, [2], 109, 175-90 (1925).

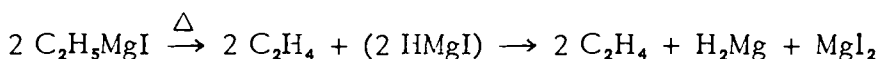
³⁵Doering and Noller, *J. Am. Chem. Soc.*, 61, 3436 (1939), found that $\text{MgBr}_2 \cdot 2\text{Et}_2\text{O}$ is markedly more soluble in an ethereal solution of *n*-butylmagnesium bromide than in ethyl ether.

³⁶See: Noller, *J. Am. Chem. Soc.*, 53, 635-43 (1931).

³⁷Milas, U. S. Patent 2,432,921, June 20, 1944; *Chem. Abstr.*, 42, P2278 (1948).

Clapp and Woodward³⁸ report that, when pyrolyzed *in vacuo* at 220°, ethylmagnesium bromide evolves pure ethylene. "By treatment of the [solid] pyrolysis product in suspension in an ether-benzene mixture of benzophenone it has been possible to obtain a 66 percent yield of benzhydrol." The pyrolysis product of methylmagnesium iodide, on the other hand, did not prove an effective reducing agent for benzophenone. These observations, however, have little or no direct bearing on the reduction mechanism proposed by Hess, Rheinboldt *et al.* (*loc. cit.*^{33, 34}).

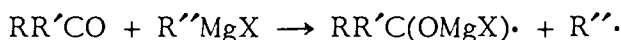
Jolibois,³⁹ had earlier studied the pyrolysis of ethylmagnesium iodide at 175°, and summarized his observations and conclusions in the equation:



He reported that ether extraction of the solid residue removes magnesium iodide, leaving magnesium hydride, which liberates hydrogen at 280°.

However attractive the notion of a hydride as the effective agent in Grignard reductions may appear to some theorists, it suffers the lethal defect that it neither provides nor admits of a reasonable explanation of asymmetric reductions (to be discussed hereafter).

Blicke and Powers (*loc. cit.*³⁰) have proposed that reaction between a Grignard reagent and an aldehyde or ketone is initiated by homolytic scission of the Grignard reagent with free-radical formation.



They assume that one or more of the following reactions may then take place:

- (1) $\text{RR}'\text{C}(\text{OMgX})\cdot + \text{R}''\cdot \rightarrow \text{RR}'\text{R}''\text{COMgX}$ (normal addition)
- (2) $\text{RR}'\text{C}(\text{OMgX})\cdot + \text{R}''\cdot \rightarrow \text{RR}'\text{CHOMgX} + \text{R}''_{(-\text{H})}$ (reduction)
- (3) $2 \text{RR}'\text{C}(\text{OMgX})\cdot \rightarrow [\text{RR}'\text{C}(\text{OMgX})\text{—}]_2$ (pinacol formation)
- (4) $2 \text{R}''\cdot \rightarrow \text{R}''_2$

To the dimerization reaction of equation 4, of course, should be added the alternatives of free-radical disproportionation (5) and attack upon the solvent (6).

- (5) $2 \text{R}''\cdot \rightarrow \text{R}''\text{H} + \text{R}''_{(-\text{H})}$
- (6) $\text{R}''\cdot + (\text{C}_2\text{H}_5)_2\text{O} \rightarrow \text{R}''\text{H} + \text{C}_2\text{H}_5\text{O}(\text{CH}_3)\text{CH}\cdot$

The evidence against such a reaction mechanism is largely negative, yet it is, in the aggregate, rather convincing. Many interactions between Grignard reagents and carbonyl compounds lead to nearly quantitative yields of the normal addition products. This is not a very probable outcome of the initial reaction step postulated. The ketyls $[\text{RR}'\text{C}(\text{OMgX})\cdot]$

³⁸Clapp and Woodward, *J. Am. Chem. Soc.*, 60, 1019-20 (1938).

³⁹Jolibois, *Compt. rend.*, 155, 353-5 (1912); *Chem. Abstr.*, 6, 2741 (1912).

are in general highly colored, yet many Grignard additions and reductions take place with little or no perceptible color development. The presence of ketyl radicals should always lead to the formation of some pinacol, yet pinacol formation has never been demonstrated (save for triarylmethylmagnesium halides) where it is also certain that metallic magnesium has been rigorously excluded.⁴⁰ The presence of free organic radicals corresponding to the Grignard reagent ($R''\cdot$) should always lead to some disproportionation, dimerization, or attack upon the solvent. In the case of isobutylmagnesium bromide and benzophenone, at least, it has been shown that the amount of isobutylene evolved corresponds quantitatively to the amount of benzhydrol produced (Noller *et al.*, *loc. cit.*³¹). In no case where a dimer has been reported, has it been shown that the amount differs materially from that which might be expected to result from the Wurtz side-reaction in the preparation of the Grignard reagent.

A slightly different free-radical mechanism, but one open to similar objections, has been proposed by Lagerev⁴¹, and accepted by Temp and Gibalevich⁴².

On the basis of the reactions of several Grignard reagents with a relatively small number of aldehydes and ketones, some of which reactions were undoubtedly complicated by enolization and condensation, Conant *et al.*⁴³ conclude that the reducing tendency of an alkyl Grignard reagent increases with the size and complexity of the alkyl group. That so simple a generalization is inadequate to cover the subject, however, is shown by the fact that neither *t*-butylmagnesium bromide⁴⁴ nor chloride⁴⁵ reduce benzophenone appreciably, whereas *n*-butylmagnesium bromide gives *ca.* 59 percent reduction^{44, 45}.

Whitmore and George (*loc. cit.*³²), have sought to relate the reducing tendency of alkyl Grignard reagents to the nature and number of *beta* hydrogen atoms in the alkyl radical; tertiary, secondary, and primary hydrogens are decreasingly effective. However, this generalization also requires some modification, for *t*-butylmagnesium bromide (with nine primary *beta* hydrogen atoms) is no more effective in the reduction of benzophenone than ethylmagnesium bromide (with only three primary *beta* hydrogen atoms).

Noller and Hilmer (*loc. cit.*⁴⁴) investigated the hypothesis, somewhat similar in principle, that the reducing tendency of an alkylmagnesium bromide might be related to the ease of dehydrobromination of the cor-

⁴⁰See, *e.g.*, Gilman and Fothergill, *J. Am. Chem. Soc.*, 51, 3149-57 (1929).

⁴¹Lagerev, *J. Gen. Chem. (U.S.S.R.)*, 6, 1766-8 (1936); *Chem. Abstr.*, 31, 4308 (1937).

⁴²Temp and Gibalevich, *Trudy Uzbekskego Gosudarst. Univ., Shornik Rabot Khim.*, 15, 95-7 (1939); *Chem. Abstr.*, 35, 4367 (1941).

⁴³Conant and Blatt, *J. Am. Chem. Soc.*, 51, 1227-36 (1929); Conant, Webb, and Mendum, *ibid.*, 51, 1246-55 (1929).

⁴⁴Noller and Hilmer, *J. Am. Chem. Soc.*, 54, 2503-6 (1932).

⁴⁵Kharasch and Weinhouse, *J. Org. Chem.*, 1, 209-30 (1936).

responding alkyl bromide in pyridine, but were unable to establish any direct correlation between these properties.

Kharasch and Weinhouse (*loc. cit.*⁴⁵) have pointed out that the reductions of aromatic ketones, such as benzophenone, are competitive with the normal addition reaction. (In the cases of many aliphatic and aliphatic-aromatic ketones, reaction may be further complicated by enolization and condensation.) Even in the simplest case, therefore—the reactions of benzophenone with a series of alkylmagnesium halides—the amount of reduction product formed is not a direct measure of the reducing tendency of the Grignard reagent. By means of competitive reactions, it was shown that the reactivity of the Grignard reagent with respect to the normal addition reaction increases markedly as the “electronegativity” of the organic radical of the Grignard reagent decreases.⁴⁶ In general the reducing power of the Grignard reagent also tends to increase (but less rapidly) with decreasing “electronegativity” of the organic radical of the Grignard reagent.* The necessary consequence is that in the case of Grignard reagents with sufficiently weakly electronegative radicals, high potential reducing power may be partially or completely masked by still greater reactivity with respect to the normal addition reaction. Table VI-II, in which the organic radicals are listed in the order of decreasing “electronegativity,” is illustrative.

It should be noted in passing that the relative rates of reactions involving “hindered” ketones or very bulky Grignard reagents, or both, may be markedly affected by steric factors.

TABLE VI-II

REDUCTION OF BENZOPHENONE BY ALKYL MAGNESIUM HALIDES

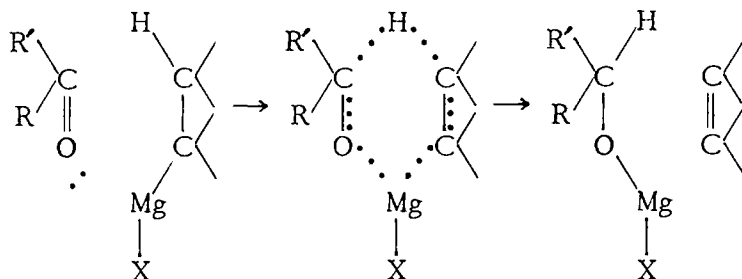
<u>R (in RMgX)</u>	<u>βH atoms</u>	<u>Reduction (%)</u>
C ₂ H ₅	3 prim.	2.0
<i>n</i> -C ₃ H ₇	2 sec.	58.0
<i>n</i> -C ₄ H ₉	2 sec.	59.0
<i>i</i> -C ₄ H ₉	1 tert.	91.0
<i>i</i> -C ₅ H ₁₁	2 sec.	30.0
(CH ₂) ₅ CH	4 sec.	7.0
(CH ₂) ₄ CH	4 sec.	94.0
<i>s</i> -C ₄ H ₉	3 prim., 2 sec.	40.0
<i>i</i> -C ₃ H ₇	6 prim.	13.0
C ₆ H ₅ (CH ₂) ₂	2 sec.	33.0
C ₆ H ₅ (CH ₂) ₃	2 sec.	20.0
<i>t</i> -C ₄ H ₉	9 prim.	0.0

⁴⁶Concerning relative electronegativities of organic radicals, see: Kharasch and Reinmuth, *J. Chem. Education*, 5, 404–18 (1928); 8, 1703–48 (1931); Kharasch, Reinmuth, and Mayo, *ibid.*, 11, 82–96 (1934); 13, 7–19 (1936).

*More specifically, the primary *beta* hydrogen atoms of the *t*-butyl group are potentially more labile (with respect to the reduction reaction under discussion) than the primary *beta* hydrogen atoms of the ethyl group; the secondary *beta* hydrogen atoms of the phenethyl group are potentially more labile than the secondary *beta* hydrogen atoms of the propyl group.

Other studies of the reducing action of Grignard reagents have been made by Stas⁴⁷, by Grignard and Delarue⁴⁸, and by Blatt and Stone.⁴⁹ Numerous examples of side-reaction reductions are recorded in the appropriate tabulations.

Concerning the actual mechanism of the Grignard reagent reduction Whitmore⁵⁰ has offered a suggestion involving the concept of a quasi six-membered ring transition state.



This scheme has several attractive features: (a) it does not conflict with any of the observed facts relating to Grignard reagent reductions of the type under discussion; (b) it accounts, in part, for the fact that a labile *beta* hydrogen atom is essential to such reductions; (c) it furnishes a possible basis for the elucidation of asymmetric reductions; and, (d) it embodies a fundamental concept that can be extended, not only to elucidation of other so-called "abnormal" reactions, but to that of the "normal" addition reaction as well.

In a study of various reactions of bornyl- and isobornylmagnesium chlorides,* Rivi re⁵¹ had found that the former reacts with esters (ethyl carbonate, ethyl formate, ethyl chloroformate) to give "normal" products almost exclusively, whereas the latter behaves predominantly as a reducing agent. Since these reagents are optically active stereoisomers it became a matter of considerable interest to ascertain whether or not the reduction of an unsymmetrical ketone with isobornylmagnesium chloride would yield an optically active secondary alcohol. With Vavon and

⁴⁷Stas, *Bull. soc. chim. Belg.*, 34, 188-90 (1925); 35, 379-86 (1926).

⁴⁸Grignard and Delarue, *Bull. soc. chim.*, [4], 47, 237 (1930).

⁴⁹Blatt and Stone, *J. Am. Chem. Soc.*, 54, 1495-9 (1932).

⁵⁰Frank C. Whitmore, paper presented before the Atlantic City meeting of the American Chemical Society, April, 1943, as quoted by Mosher and LaCombe, *J. Am. Chem. Soc.*, 72, 3994-9 (1950).

* The Grignard reagent obtained in 60-70 percent yields by the treatment of ethereal pinene hydrochloride with magnesium apparently consists of an equimolecular mixture of bornyl- and isobornylmagnesium chlorides. The "isomerized" Grignard reagent obtained by heating such a mixture in xylene at 140° for three hours is substantially pure bornylmagnesium chloride. The residual Grignard reagent remaining after partial (ca. 65 percent) carbonation of the Grignard reagent mixture derived from pinene hydrochloride is substantially pure isobornylmagnesium chloride.

⁵¹Rivi re, *Ann. chim.*, [12], 1, 157-231 (1946).

Angelo,⁵² Rivière found that acetophenone does indeed undergo asymmetric reduction with isobornylmagnesium chloride. The results obtained in a subsequent extension of the study⁵³ to a total of six ketones of the RCOC_6H_5 type are summarized in Table VI-III.

TABLE VI-III
REDUCTION OF UNSYMMETRICAL KETONES WITH
ISOBORNYLMAGNESIUM CHLORIDE

RCOC_6H_5	Yield (%) of $\text{RCH(OH)C}_6\text{H}_5$	Optical Activity of Product	Optical Activity of Pure (+)- $\text{RCH(OH)C}_6\text{H}_5$
$\text{CH}_3\text{COC}_6\text{H}_5$	55	$[\alpha]_{578} 20.10^\circ$	$[\alpha]_{578} 54.86^\circ$
$\text{C}_2\text{H}_5\text{COC}_6\text{H}_5$	50	$[\alpha]_{\text{D}} 10.60^\circ$	$[\alpha]_{\text{D}} 55.54^\circ$
$n\text{-C}_3\text{H}_7\text{COC}_6\text{H}_5$	50	$[\alpha]_{\text{D}} 26.70^\circ$	$[\alpha]_{\text{D}} 57.21^\circ$
$i\text{-C}_3\text{H}_7\text{COC}_6\text{H}_5$	80	$[\alpha]_{\text{D}} 26.40^\circ$	$[\alpha]_{\text{D}} 47.66^\circ$
$n\text{-C}_4\text{H}_9\text{COC}_6\text{H}_5$	44	$[\alpha]_{\text{D}} 21.10^\circ$	$[\alpha]_{\text{D}} 40.83^\circ$
$s\text{-C}_4\text{H}_9\text{COC}_6\text{H}_5$	90	$[\alpha]_{\text{D}} 25.90^\circ$	$[\alpha]_{\text{D}} 36.00^\circ$

Mosher and La Combe⁵⁴ have investigated the action of "dextrorotatory" 2-methylbutylmagnesium chloride* on pinacolin under a variety of experimental conditions, and have obtained 9.0–35.6 percent yields of pinacolyl alcohol ranging in optical activity from $[\alpha]_{\text{D}}^{20} + 0.42$ to $[\alpha]_{\text{D}}^{20} + 0.70$, indicating that the reduction products contain the dextro isomer in 13.0–16.1 percent excess.[†]



$[\text{H}_2\text{C}=\text{C}(\text{O})-t\text{-C}_4\text{H}_9]^{-}\text{MgCl}^{+}$ (11.1–39.5%) + tertiary alcohol and/or

ketol (8.1–37.9%) + $\text{H}_2\text{C}=\text{C}(\text{CH}_3)\text{C}_2\text{H}_5$ (6.2–31.2%) + DL- and

$(+)\text{-CH}_3(t\text{-C}_4\text{H}_9)\text{CHOH}$ (9.0–35.6%)

Whereas it appears improbable that any vague inductive effect of an optically asymmetric reaction medium would suffice to instigate a partially asymmetric synthesis of any kind,[†] it seems reasonable to seek an

⁵²Vavon, Rivière, and Angelo, *Compt. rend.*, 222, 959–61 (1946); *Chem. Abstr.*, 40, 4365 (1946).

⁵³Vavon and Angelo, *Compt. rend.*, 224, 1435–7 (1947); *Chem. Abstr.*, 41, 6221 (1947).

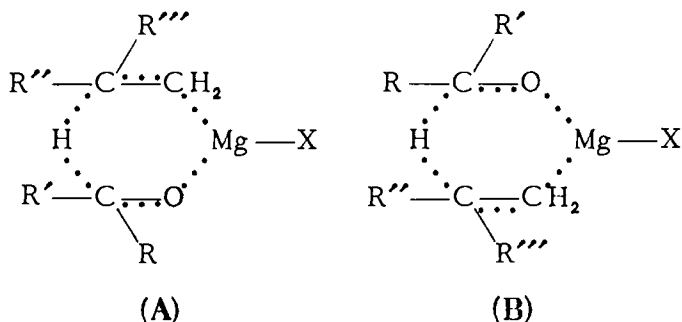
⁵⁴Mosher and LaCombe, *J. Am. Chem. Soc.*, 72, 3994–9 (1950).

* Prepared from $(+)\text{-CH}_3(\text{C}_2\text{H}_5)\text{CHCH}_2\text{Cl}$ of 94–96% optical purity.

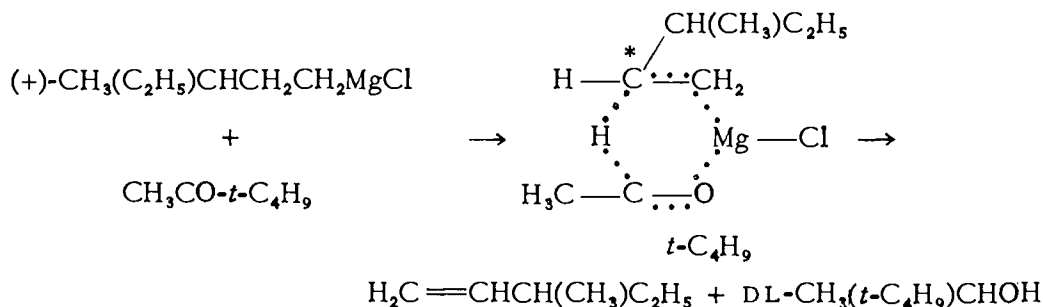
[†] The pure optical isomer, $(+)\text{-CH}_3(t\text{-C}_4\text{H}_9)\text{CHOH}$, has a specific rotation $[\alpha]_{\text{D}}^{20} + 7.71$.

[†] In this connection it may be noted that Tarbell and Paulson, *J. Am. Chem. Soc.*, 64, 2842–4 (1942), treated phenylmagnesium bromide, prepared in (+)-2-methoxybutane, with acetaldehyde and obtained 60–68 percent yields of the racemic addition product, DL- $\text{CH}_3(\text{C}_6\text{H}_5)\text{CHOH}$. Cohen and Wright, *Abstracts of Papers*, 121st Meeting, A.C.S., Buffalo, N. Y., March 23–27, 1952, p. 32K, operating in (+)-2,3-dimethoxybutane, or in benzene or toluene to which at least one molecular equivalent of the optically active ether had been added, obtained

explanation of the phenomenon in an intermediate reaction complex capable of existing in two stereoisomeric forms, one of which is presumably somewhat favored over the other by steric effects. Mosher and La Combe (*loc. cit.*⁵⁴) have offered such an interpretation based on the concept of a quasi six-membered ring intermediate. Unfortunately, none of the commercially-available model sets is especially well adapted to the illustration of this thesis, and planar diagrams are perhaps even less satisfactory. However, the general sense of the argument may be conveyed by the following formulae (A, B).



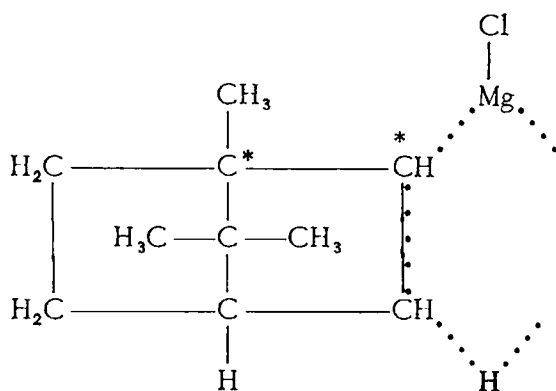
Mosher and La Combe⁵⁵ assume further that one member of the postulated six-membered ring of the transition state must be an asymmetric center, and believe that the symmetrical reduction of pinacolin by (+)-3-methylpentylmagnesium chloride supports this view.



Indeed, superficial examination of their argument might lead the casual reader to conclude that the reducing hydrogen atom must be one attached to an asymmetric center, but this of course need not be the case, for in isobornylmagnesium chloride one asymmetric center is the carbon atom adjacent to magnesium and the other cannot be a member of the postulated transition-state ring. In this case the reducing hydrogen atom must be one of two attached to an inactive *beta* carbon atom.

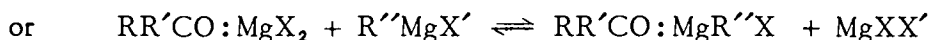
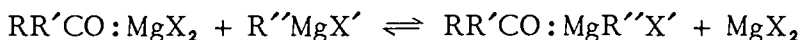
products with a small but significant (1-2 percent) degree of activity when a Grignard reagent prepared from inactive *s*-butyl chloride was treated with benzaldehyde or other co-reactants. In such cases, however, optically active ethers or amines [see Betti and Lucchi, *Boll. sci. facolta chim. ind., Bologna*, 1940, No. 1-2, 2-5; *Chem. Abstr.*, 34, 2354 (1940)] constitute somewhat more than an asymmetric environment, for they are capable of entering into the transition-state intermediate through complex formation with the Grignard reagent.

⁵⁵Mosher and La Combe, *J. Am. Chem. Soc.*, 72, 4991-4 (1950).



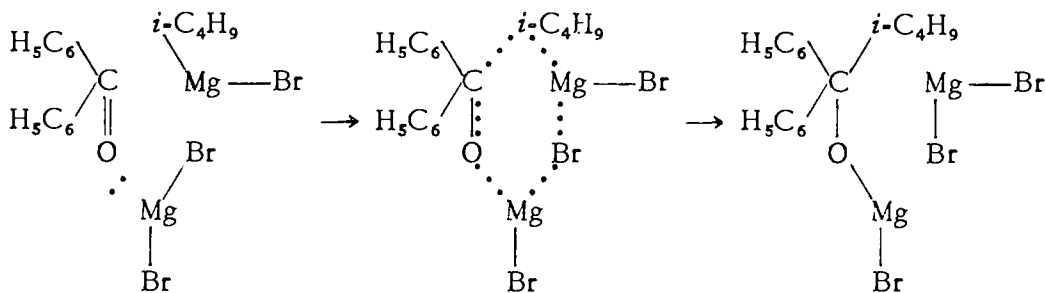
The fundamental necessity of the hypothesis is, of course, that the postulated transition state shall be capable of two stereoisomeric forms (A' , B'), one of which is sterically favored over the other. It may well be that no acyclic Grignard reagent other than one with the reducing hydrogen atom attached to an asymmetric carbon atom can enter into a transition state fulfilling the stated conditions; if so, however, the fact may be regarded as, in a sense, coincidental.

Possibility of suppressing Grignard reagent reduction. The respective mechanisms tentatively proposed to account for "normal" addition of a Grignard reagent at a carbonyl double bond and for the Grignard reagent reduction of a carbonyl group suggest the possibility of suppressing the latter in favor of the former. To this end labilization of the carbonyl double bond might be effected by complex formation with an organometallic compound incapable of either reduction or rapid "normal" 1,2 carbonyl addition [e.g.: $(C_6H_5)_2Cd$, C_6H_5ZnX , $(CH_3)_2Hg$, MgX_2]. "Normal" addition of a reducing Grignard reagent might then take place by reaction of the reagent with a previously-formed complex—providing that complete exchange in the senses



is not too rapid in comparison with addition.

For example:

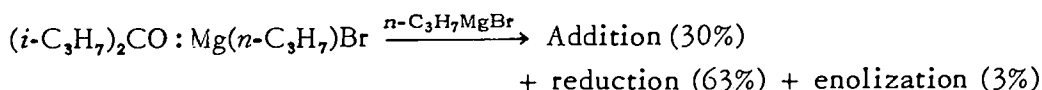


Since the first draft of this discussion was written, Swain⁵⁶ has published a note presenting the same idea, and reporting that in the case of

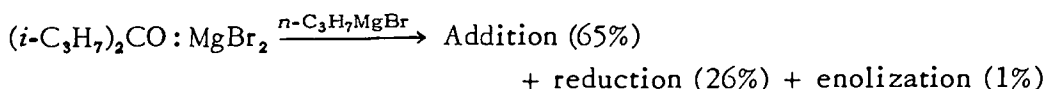
⁵⁶Swain and Boyles, *J. Am. Chem. Soc.*, 73, 870-2 (1951).

the reaction of *n*-propylmagnesium bromide with diisopropyl ketone, at least, the suggested technique is indeed capable of enhancing the yield of addition product at the expense of the yield of reduction product.

Employing the experimental conditions of Whitmore and George⁵⁷, Swain obtained quantitative results very similar to theirs, which may be summarized in the equation:

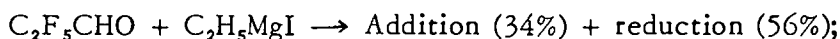


Employing a variation of the suggested technique, he obtained the following results:



In terms of the working hypothesis investigated it may be said (ignoring the relatively insignificant complication introduced by enolization) that the amount of reduction observed in the second experiment (26 percent) is roughly indicative of the amount of complex exchange that took place during the reaction period. Such exchange could be minimized by saturation of the Grignard reagent solution with magnesium bromide prior to its combination with the ketone-halide complex solution (or suspension).

A similar suppression of reduction with consequent facilitation of addition has been reported by McBee *et al.*^{57,1} in the case of the reaction of ethylmagnesium iodide with pentafluoropropionaldehyde:



Alkoxide reduction. Marshall⁵⁸ claims to have been the first to observe that in reactions with a Grignard reagent, an excess of aldehyde operates as an oxidizing agent. He found, for example that when phenylmagnesium bromide is treated with two equivalents of benzaldehyde, the products are benzyl alcohol and benzophenone, together with a small amount of material which he designated as symmetrical tetraphenylethane. This is clearly a special case of the Meerwein-Ponndorf-Verley oxidation-reduction usually effected with aluminum alkoxides.⁵⁹ Indeed, among the alkoxides investigated as reducing agents by Meerwein⁶⁰ was ethoxymagnesium chloride. (Diethoxymagnesium proved too alkaline, and led to more condensation than reduction.) With ethoxymagnesium chloride,

⁵⁷Whitmore and George, *J. Am. Chem. Soc.*, 64, 1239-42 (1942).

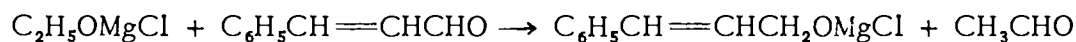
^{57,1}McBee, Pierce, and Higgins, *J. Am. Chem. Soc.*, 74, 1736-7 (1952).

⁵⁸Marshall, *J. Chem. Soc.*, 105, 527-34 (1914); 107, 509-23 (1915).

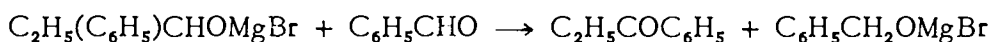
⁵⁹See: A. L. Wilds, "Reduction with Aluminum Alkoxides," Chapter 5, Vol. II of "Organic Reactions," edited by Roger Adams, John Wiley & Sons, Inc., New York, 1944, pp. 178-223.

⁶⁰Meerwein and Schmidt, *Ann.*, 444, 221-38 (1925).

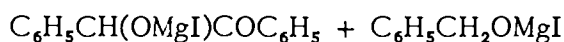
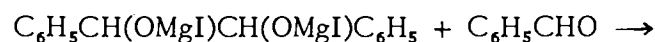
reduction products of the following aldehydes were obtained in the indicated percentage yields: cinnamaldehyde (*ca.* 80), benzaldehyde (76), anisaldehyde (75), *p*-nitrobenzaldehyde (70), crotonaldehyde (60), citronellal (70–80). From the cinnamaldehyde reaction, 51 percent of the theoretical quantity of acetaldehyde was isolated.



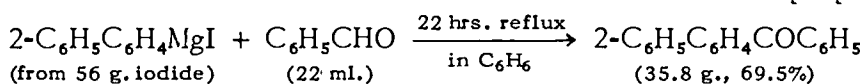
Meisenheimer,⁶¹ who had apparently overlooked Marshall's work, used an excess of benzaldehyde in some experiments in a study of the reducing action of Grignard reagents. In a later study⁶² he investigated the residues which were always formed in considerable amount when ethylmagnesium bromide was allowed to react with an excess of benzaldehyde, and succeeded in isolating and identifying propiophenone. He recognized and pointed out the relationship of this work to that of Meerwein and Schmidt (*loc. cit.*⁶⁰).



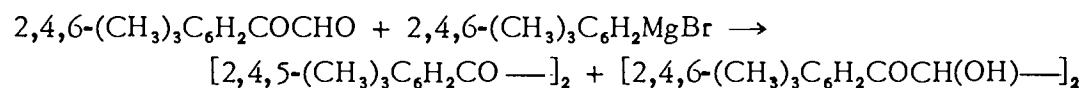
Shankland and Gomberg⁶³ have investigated the reducing action of several alkoxy magnesium iodides on a variety of aldehydes and ketones. In general, these reactions appear to be rather rapid. For example, at the boiling point of ether, the diiodomagnesium derivative of dihydrobenzoïn effects a 95.3 percent reduction of benzaldehyde (as measured by the yield of benzoïn) in fifteen minutes. (In general, yields of alcohols isolable are about 10 percent lower than benzoïn yields.)



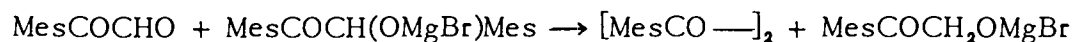
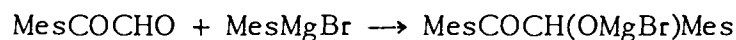
Bradsher⁶⁴ has used a similar reaction as a method of ketone preparation.



Gray and Fuson⁶⁵ describe a reaction which is probably best explained as a Meerwein oxidation-reduction combined with a condensation.



The overall reaction may be broken down into the following steps:*



⁶¹Meisenheimer, *Ann.*, 442, 180–210 (1925).

⁶²Meisenheimer, *Ann.*, 446, 76–86 (1926).

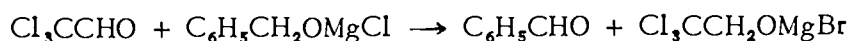
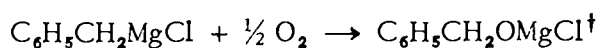
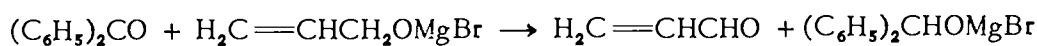
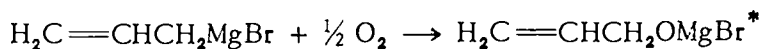
⁶³Shankland and Gomberg, *J. Am. Chem. Soc.*, 52, 4973–8 (1930).

⁶⁴Bradsher, *J. Am. Chem. Soc.*, 66, 45–6 (1944).

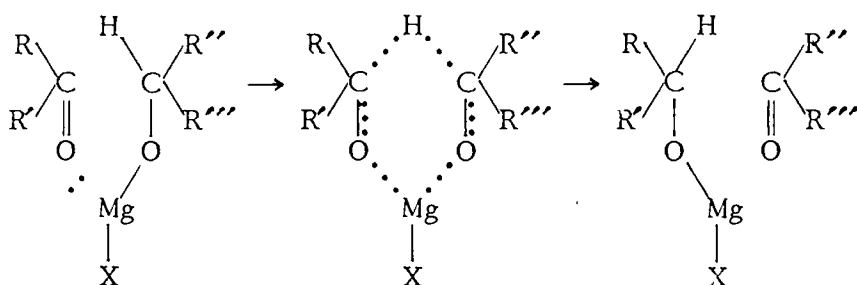
⁶⁵Gray and Fuson, *J. Am. Chem. Soc.*, 56, 739–41 (1934).

*Mes = mesityl = 2,4,6-(CH₃)₃C₆H₂—.

Paradoxically enough, oxygen contamination of a Grignard reagent which is in itself incapable of effecting reduction may lead to a Meerwein reduction. This is probably the cause of the small amount of reduction product observed by Kharasch and Weinhouse (*loc. cit.*⁶⁵) in the treatment of benzophenone with allylmagnesium bromide, and by Gilman and Abbott⁶⁶ in the treatment of chloral with benzylmagnesium chloride.



For the alkoxide reductions, as for the Grignard reagent reductions, a transition state involving a quasi six-membered ring may be postulated.



At this writing no report of an asymmetric reduction of this kind effected with the aid of an optically active halomagnesium alkoxide has come to the attention of the present authors. However, partially asymmetric reactions have been reported in the closely analogous cases of carbonyl reductions with optically active potassium and aluminum alkoxides.^{67, 68, 69}

Magnesium halide reduction. Schmidlin⁷⁰ observed that the reaction of triphenylmethylmagnesium chloride with benzophenone in the presence of excess magnesium powder leads to the production of benzpinacol rather than of the expected pentaphenylethanol. It has since been shown by Gilman and Fothergill⁷¹ that, in the cases of triphenylmethylmagnesium bromide and chloride, the presence of metallic magnesium is unnecessary to pinacol formation.

⁶⁶Gilman and Abbot, *J. Org. Chem.*, 8, 224-9 (1943).

*These equations represent stoichiometrical relationships only. Concerning the oxygenation of Grignard reagents see: Chapter XX, Reactions of Grignard Reagents with Oxygen, etc.

⁶⁷Doering and Aschner, Abstracts of Papers, 112th meeting of the American Chemical Society, New York, September, 1947, p. 21L.

⁶⁸Doering and Young, *J. Am. Chem. Soc.*, 72, 631 (1950).

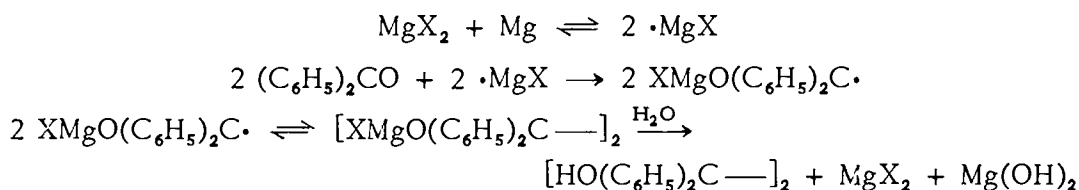
⁶⁹Jackman, Mills, and Shannon, *J. Am. Chem. Soc.*, 72, 4814-5 (1950).

⁷⁰Schmidlin, *Ber.*, 39, 4198-204 (1906).

⁷¹Gilman and Fothergill, *J. Am. Chem. Soc.*, 51, 3149-57 (1929).

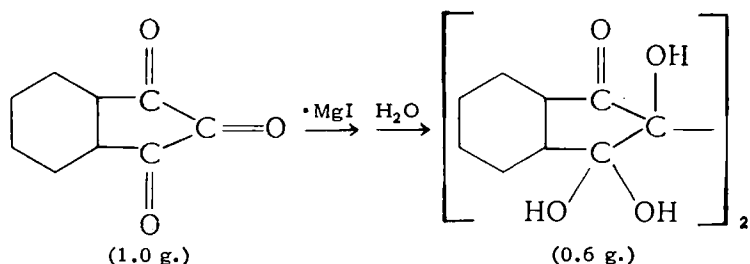
The nature of this reaction has been clarified by the work of Gomberg *et al.*,⁷² who showed that similar reductions of aromatic ketones may be effected with magnesium-magnesium iodide or magnesium-magnesium bromide, but not with magnesium-magnesium chloride, mixtures. Neither magnesium alone nor magnesium halide alone is effective. The reaction solutions are intensely colored, and do not obey Beer's law.

The reactions are explained as a consequence of the ability of magnesium bromide (or iodide), in contact with metallic magnesium to behave as though it were in equilibrium with the magnesious halide.

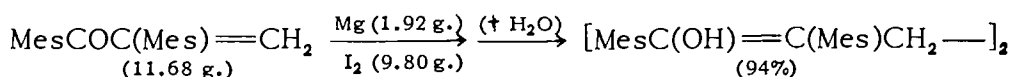


The intense coloration is attributed to the ketyl radical $[\text{XMgO}(\text{C}_6\text{H}_5)_2\text{C}\cdot]$.

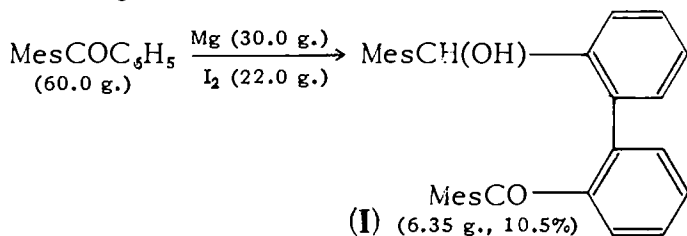
By such means Schönberg and Moubasher⁷³ have succeeded in reducing 1,2,3-indantrione to hydrintanin.



An interesting variation on the usual theme of pinacol formation in the case of an α, β -unsaturated "hindered" ketone is reported by Fuson *et al.*,^{74,*}



A different, though formally analogous, dimerization has been observed by Fuson and Hornberger.⁷⁵



⁷²(a) Gomberg and Bachmann, *J. Am. Chem. Soc.*, 49, 236-57 (1927); (b) Gomberg, Bailar, and Van Natta, *Rec. trav. chim.*, 48, 847-51 (1929); (c) Gomberg and Shankland, *J. Am. Chem. Soc.*, 51, 306-9 (1929); (d) Gomberg and Bailar, *J. Am. Chem. Soc.*, 51, 2229-38 (1929).

⁷³Schönberg and Moubasher, *J. Chem. Soc.*, 1949, 212-4.

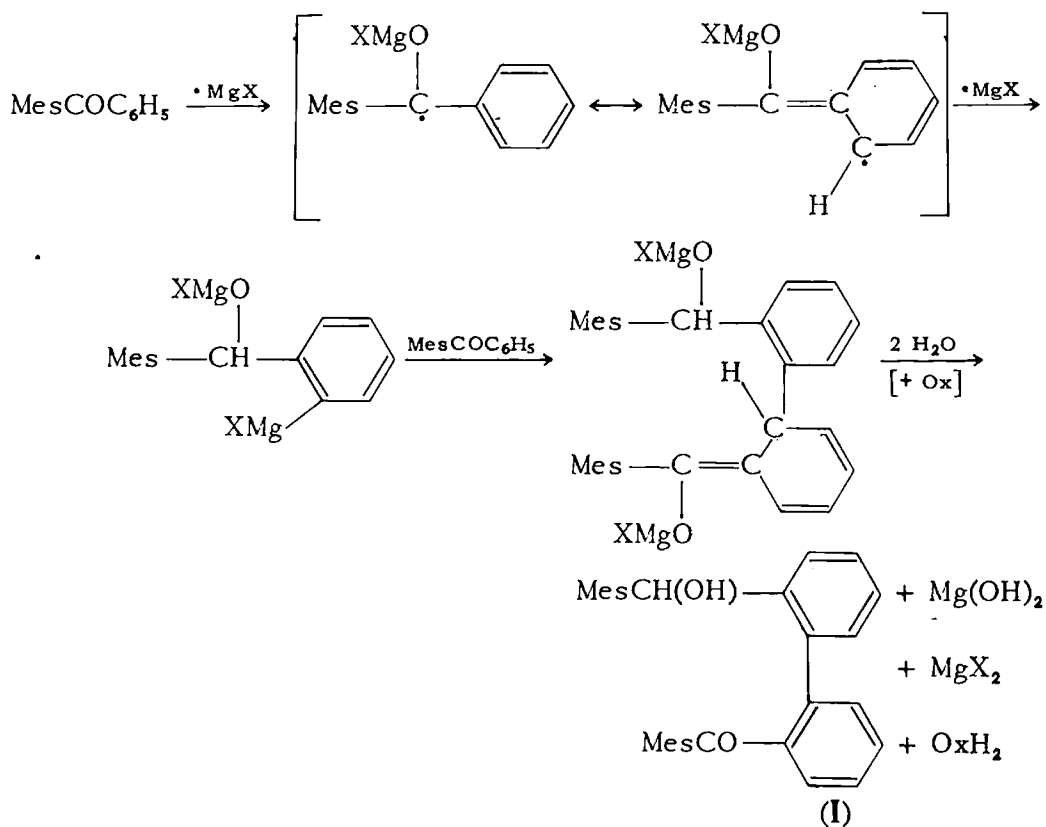
⁷⁴Fuson, Byers, and Rachlin, *J. Am. Chem. Soc.*, 64, 2891-3 (1942).

* Mes = mesityl = 2,4,6-(CH₃)₃C₆H₂—.

⁷⁵Fuson and Hornberger, *J. Org. Chem.*, 16, 631-6 (1951).

Possibly the resonant ketyl radicals combine to form the equivalent of a dihydride of the product here represented, and two extremely labile hydrogen atoms (or the equivalent) are eventually removed by a suitable hydrogen acceptor, as, *e.g.*, atmospheric oxygen. In view of the low yield reported, even the possibility of a Meerwein oxidation-reduction cannot be rejected.

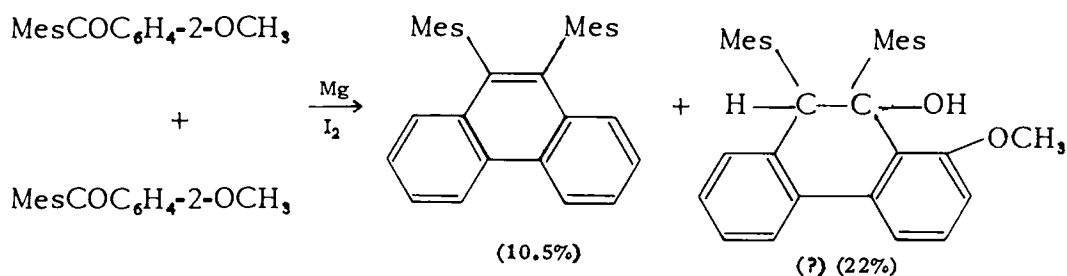
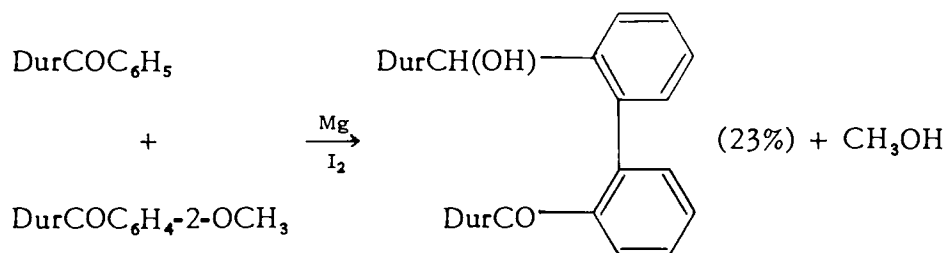
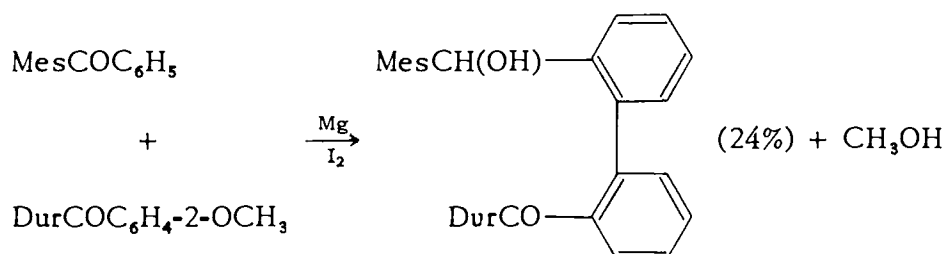
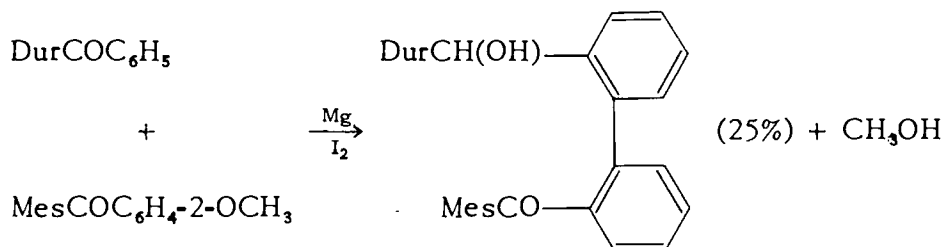
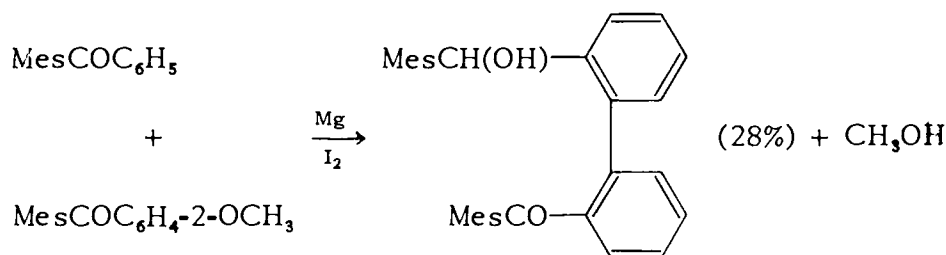
However, it is conceivable that this reaction actually has more in common with the 1,4-additions of Grignard reagents to conjugated carbonyl systems (*q.v.*) than with the generally accepted ketyl dimerization scheme formulated to elucidate the ordinary magnesious halide reductions of ketones.* It has been shown by Gomberg and Bachmann⁷⁶ that at least some free radicals are capable of combining with magnesious halide to form Grignard reagents (see Grignard Reagents from Free Radicals, Chapter II). A scheme embodying the concept of Grignard reagent formation and 1,4-addition to a conjugated carbonyl system might be outlined as follows:



*Incidentally, as will become apparent in the succeeding discussion, it would be possible to interpret the ordinary pinacol production as involving the formation of a Grignard reagent from a ketyl free radical and the 1,2-addition of the Grignard reagent so derived to the carbonyl double bond of the ketone, although there seems no good reason to do so.

⁷⁶Gomberg and Bachmann, *J. Am. Chem. Soc.*, 52, 2455-61 (1930).

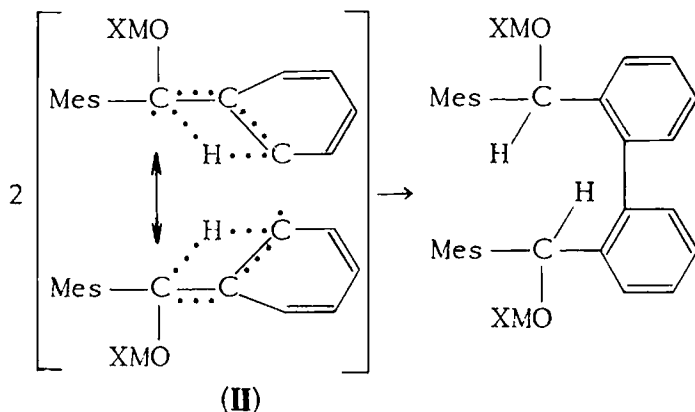
In its essentials (though with minor modifications) this is the scheme proposed by Fuson and Hornberger⁷⁷ to account for similar reductive couplings involving methoxyl group displacement* (see also 1,4-Additions Involving Cleavage, p. 231).



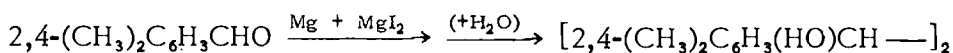
⁷⁷Fuson and Hornberger, *J. Org. Chem.*, 16, 637-42 (1951).

*Dur = duryl = 2,3,5,6-(CH₃)₄C₆H—.

Although attractive enough in itself, the reaction scheme proposed by Fuson and Hornberger (*loc. cit.*⁷⁷) does not seem readily adaptable to elucidation of the formation of mesityl 2'-(mesitylhydroxymethyl)-2-biphenyl ketone (I), observed, though (apparently erroneously) reported as pinacol formation, by Kharasch *et al.*⁷⁸ in the reaction of phenylmagnesium bromide with mesitoyl chloride in the presence of cobaltous chloride (see Chapter IX, Coupling). In the reaction cited there would appear to be no reasonable hypothesis of ketone "dimer" formation alternative to postulation of mutual combination of free radicals of type II, in which M signifies a metal (Co or Mg), and X signifies a halogen (Cl or Br).

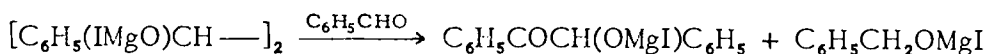
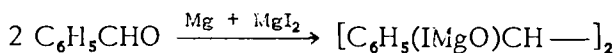


Some aldehydes also undergo magnesiumous halide reductions, as in the case of 2,4-dimethylbenzaldehyde, reported by Fuson and Ward.⁷⁹



As might be expected, and as was observed by Law⁸⁰ in the alkaline electrolytic reductions of *p*-tolualdehyde, and 2,4-dimethyl- and 3,5-dimethylbenzaldehydes, the product is obtained in two stereoisomeric forms—presumably the meso and the racemic.

In the presence of an excess of aldehyde the magnesiumous halide reduction may be combined with a Meerwein oxidation-reduction, as in a case reported by Gomberg and Bachmann.⁸¹ The second step of the reaction appears to be very rapid as compared to the first.



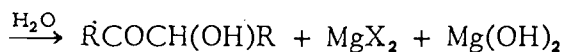
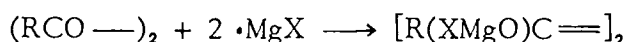
⁷⁸Kharasch, Morrison, and Urry, *J. Am. Chem. Soc.*, 66, 368-71 (1944).

⁷⁹Fuson and Ward, *J. Am. Chem. Soc.*, 68, 521-2 (1946).

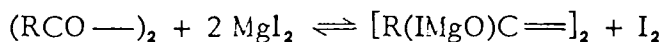
⁸⁰Law, *J. Chem. Soc.*, 91, 748-60 (1907).

⁸¹Gomberg and Bachmann, *J. Am. Chem. Soc.*, 52, 4967-72 (1930).

The magnesious halide reduction of a benzil leads to benzoïn enolate formation.^{82, 83}

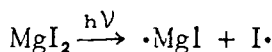


According to Gomberg and Van Natta (*loc. cit.*^{82b}), similar reductions are effected by magnesium iodide alone in the absence of metallic magnesium. This phenomenon is attributed to the equilibrium:



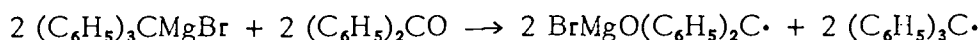
In several experiments free iodine ranging in amount from 16 to 50 percent of the theoretical was determined by titration.

Although Gomberg's interpretation of the magnesium iodide reduction reaction is by no means implausible, the observation of Stewart and Ubbelohde⁸⁴ that oxygen-free solutions of magnesium iodide in ether become brown and cloudy on exposure to daylight appears relevant to the point under consideration. This observation would seem to constitute sufficient evidence for the dissociation:



A comparison between the behaviors of the dark and illuminated reduction systems would be of some interest.

In the light of the studies of Gomberg and his co-workers, it appears fairly evident that in the reductions effected by Grignard reagents with extremely weak electronegative organic radicals (specifically, triaryl-methylmagnesium halides), magnesious halide is the essential reducing agent.



In the cases in which pinacol formation has been reported as resulting from the action of alkyl- or arylmagnesium halides on aromatic ketones,⁸⁵ there can be little doubt that the active reducing agent is magnesious halide arising from the interaction of residual magnesium with magnesium halide formed as a product of a Wurtz side-reaction or resulting from the Schlenk equilibrium. Mere siphoning of the Grignard solution may not be relied upon to insure the removal of finely suspended magnesium, and even a glass-wool plug is sometimes an insufficient safeguard.

⁸²(a) Gomberg and Bachmann, *J. Am. Chem. Soc.*, 49, 2584-92 (1927); (b) Gomberg and Van Natta, *J. Am. Chem. Soc.*, 51, 2238-45 (1929).

⁸³Fuson and Corse, *J. Am. Chem. Soc.*, 61, 975 (1939).

⁸⁴Stewart and Ubbelohde, *J. Chem. Soc.*, 1949, 2649-56.

⁸⁵See, e.g.: Barnett, Cook, and Nixon, *J. Chem. Soc.*, 1927, 505-12; Davies, Dixon, and Jones, *ibid.*, 1930, 1916-21; Arbuzov and Arbuzova, *J. Gen. Chem. (U.S.S.R.)*, 2, 388-96 (1932); *Chem. Abstr.*, 27, 974 (1933); *British Chem. Abstr.*, 1932A, 1250; *Chem. Zentr.*, 1933, 1, 2940.

Gilman and Fothergill (*loc. cit.*⁷¹) have shown that, in the presence of free magnesium, one of the products of reaction of benzophenone with alkylmagnesium iodides and bromides (but not chlorides) is benzpinacol. When free magnesium was carefully excluded, no pinacol formation could be detected.

That metallic impurities in the magnesium employed in the preparation of the Grignard reagent may, however, occasionally play a part in such reactions is suggested by various observations of Kharasch and co-workers.⁸⁶ For example, isobutylmagnesium bromide ordinarily reacts with benzophenone to give high yields (of the order of 90 percent) of benzhydrol, the Grignard reagent reduction product. When about 2 mole percent of manganous chloride is present in the reaction system, however, benzhydrol formation becomes negligible, and benzpinacol is formed to the extent of 90 percent or more. Chromous and ferric chlorides have similar, but less pronounced, effects.^{86a} With methylmagnesium bromide, benzophenone undergoes "normal" addition to give the tertiary alcohol in a yield of the order of 95 percent. When about 2 mole percent of cobaltous chloride is present in the reaction system the yield of tertiary alcohol is diminished to about 2 percent, and benzpinacol is formed in about 93 percent yield. Ferric chloride has a similar, but less pronounced effect.^{86c} With methylmagnesium bromide, isophorone (3,5,5-trimethyl-2-cyclohexen-1-one) forms the "normal" 1,2-addition product in *ca.* 91 percent yield; in the presence of 1 mole percent of cobaltous chloride yields of pinacol range from 67.0 to 78.5 percent.^{86b}

ENOLATE FORMATION BY GRIGNARD REAGENTS

Grignard⁸⁷ observed that when methylmagnesium iodide reacts with ethyl ethylacetoacetate, considerable amounts of methane are evolved and correspondingly large quantities of the keto ester are recovered (the yield of the expected hydroxy ester being rather small). He correctly ascribed this phenomenon to "enolization" (*i.e.*, to enolate formation).

Zelinsky⁸⁸ found that, although acetylacetone reacts readily with methylmagnesium iodide, the expected glycol is obtained in negligible quantities. He drew the conclusion, now known to be unjustified, that acetylacetone is a "pseudoketone," existing largely in the enolic form.

In an early study of the applicability of Tschugaeff's⁸⁹ suggested method for the quantitative evaluation of hydroxyl groups in organic substances, Hibbert and Sudborough⁹⁰ included acetoacetic ester and found

^{86(a)}Kharasch, Kleiger, Martin, and Mayo, *J. Am. Chem. Soc.*, 63, 2305-7 (1941); (b) Kharasch and Tawney, *J. Am. Chem. Soc.*, 63, 2308-15 (1941); (c) Kharasch and Lambert, *J. Am. Chem. Soc.*, 63, 2315-6 (1941).

⁸⁷Grignard, *Compt. rend.*, 134, 849-51 (1902); *J. Chem. Soc.*, 82, 1, 420.

⁸⁸Zelinsky, *Ber.*, 35, 2138-40 (1902).

⁸⁹Tschugaeff, *Ber.*, 35, 3912-4 (1902).

⁹⁰Hibbert and Sudborough, *J. Chem. Soc.*, 85, 933-8 (1904).

that, with methylmagnesium iodide in amyl ether, about 90 percent of the amount of methane equivalent to one hydroxyl group is liberated.

Zerewitinoff,⁹¹ in the second of his classical series of studies on the determination of "active" hydrogen in organic compounds, included, among other enolizable compounds, acetylacetone, benzoylacetone, and acetoacetic ester. He found that, when treated with methylmagnesium iodide in amyl ether at 100°, they all gave rise to methane evolution equivalent to one "active" hydrogen atom per molecule. (At 20° the yield of methane was somewhat less.)

Dupont⁹² reported that 2,2,5,5-tetramethyltetrahydrofuran-3-one "reacts as an enol" with ethyl-, *n*-propyl-, isobutyl-, phenyl- and *p*-tolylmagnesium bromides. With methyl-, ethynyl- and benzylmagnesium bromides, it yields the expected alcohols. 2,5-Dimethyl-2,5-diethyltetrahydrofuran-3-one is said to "react quantitatively as the enol."

Bhagvat and Sudborough⁹³ examined a number of aldehydes, ketones, and keto esters by the method of Zerewitinoff and announced that, whereas most aldehydes and ketones react "normally" (*i.e.*, additively), *beta* ketonic esters and *alpha*, *gamma* diketones yield large volumes of gas.

Ethylzinc iodide was recommended by Job and Reich⁹⁴ as a suitable reagent for the study of enols by the Zerewitinoff method on the ground that it does not react additively with carbonyl or ester groups. That it does not react solely with the enolic form, however, is evidenced by their observation that it "enolizes" acetoacetic ester slowly, but malonic ester and acetylacetone quite rapidly.

Using camphor, a very unreactive and slowly enolizable ketone, as test material, Bredt-Savelsburg⁹⁵ found that the rate of enolization is dependent upon the temperature, upon the particular Grignard reagent employed, and upon the solvent. The low rate of enolization of camphor is illustrated in the data of Table VI-IV. Other illustrative data are

TABLE VI-IV

RATE OF ENOLIZATION OF CAMPHOR BY METHYLMAGNESIUM
IODIDE IN ETHYL ETHER SOLUTION AT 20°

<u>Time (hrs.)</u>	<u>Enolization (%)</u>
0.5	13.0
5.0	14.1
10.0	14.9
25.0	30.4
40.0	44.7

⁹¹Zerewitinoff, *Ber.*, 41, 2233-43 (1908).

⁹²Dupont, *Compt. rend.*, 154, 519-21 (1912); *Chem. Zentr.*, 1912, 1, 1318.

⁹³Bhagvat and Sudborough, *Proc. Asiatic. Soc. Bengal*, 15, cxxvi (1919); *Chem. Abstr.*, 14, 1674 (1920).

⁹⁴Job and Reich, *Bull. soc. chim.*, [4], 33, 1414-33 (1923).

⁹⁵Bredt-Savelsburg, *J. prakt. chem.*, [2], 107, 65-85 (1924).

assembled in Table VI-V. The effect of temperature is illustrated by the enolization of camphor by methylmagnesium iodide in ethyl ether to the extent of 6.8 percent at 0° and of 14.8 percent at 20° in the course of ten hours.

TABLE VI-V
EFFECT OF SOLVENT AND OF NATURE OF GRIGNARD REAGENT UPON
RATE OF ENOLIZATION OF CAMPHOR AT ROOM TEMPERATURE

<u>RMgX</u>	<u>Solvent</u>	<u>Time (hrs.)</u>	<u>Enolization (%)</u>
CH ₃ MgI	Am ₂ O	36	ca. 3.6
CH ₃ MgI	C ₆ H ₆	30	32.5
CH ₃ MgI	Et ₂ O	40	44.7
CH ₃ MgI	Et ₂ O	10	14.8
CH ₃ MgBr	Et ₂ O	10	24.0
CH ₃ MgCl	Et ₂ O	10	28.2
C ₂ H ₅ MgI	Et ₂ O	43	14.0
C ₆ H ₅ MgBr	Am ₂ O	24	21.0
1-C ₁₀ H ₇ MgBr	Et ₂ O	24	25.0

Grignard and Savard⁹⁶ investigated the action of some twenty-two Grignard reagents on pulegone (2-methyl-5-isopropylidenecyclohexanone) at 40°. Because it was not demonstrated that the gases evolved were due solely to enolization (rather than to a combination of enolization and reduction), their tabulation of data is here reproduced in part only in Table VI-VI.

TABLE VI-VI
ENOLIZATION OF PULEGONE BY VARIOUS NON-REDUCING GRIGNARD
REAGENTS IN ETHYL ETHER AT 40°

<u>Grignard Reagent</u>	<u>Enolization (%)</u>
CH ₃ MgI	26
CH ₃ MgBr	33
C ₆ H ₅ MgI	35
C ₆ H ₅ MgBr	41
C ₆ H ₅ CH ₂ MgI	39
C ₆ H ₅ CH ₂ MgBr	44

In order to study the competition between the "normal" addition and the enolization reactions, Kohler *et al.*,⁹⁷ devised a modification of the Zerewitinoff apparatus, commonly called the "Grignard machine," which facilitates measurement, not only of the amount of methane evolved, but of the amount of methylmagnesium iodide consumed. Their data are summarized in Table VI-VII. In all cases, reactants were heated to completion of reaction (Grignard reagent in excess).

⁹⁶Grignard and Savard, *Bull. soc. chim. Belg.*, 36, 97-107 (1927).

⁹⁷Kohler, Stone, and Fuson, *J. Am. Chem. Soc.*, 49, 3181-8 (1927); Kohler and Richtmyer, *J. Am. Chem. Soc.*, 52, 3736-8 (1930).

TABLE VI-VII

REACTION OF METHYLMAGNESIUM IODIDE WITH VARIOUS KETONES
IN ISOAMYL ETHER (QUANTITIES IN MILLIMOLES)

<u>Ketone</u>	<u>Am't. Ketone</u>	<u>Am't. Gas Evolved</u>	<u>Am't. G. R. Consumed</u>
$(C_6H_5)_2CO$	1.77	0.03	1.74
$(C_6H_5CO)_2$	0.97	0.09	1.95
$C_6H_5COCH(OH)C_6H_5$	1.08	1.10	2.15
$(C_6H_5CO)_2CH_2$	0.50	0.53	1.04
$(C_6H_5CO)_2CHCH_3$	0.50	0.08	1.05
$(C_6H_5CO)_2CHBr$	0.50	0.03	1.02
$CH_3COC_6H_5$	2.28	0.33	2.27
$CH_3COC_6H_5$	2.31	0.36	2.30
$C_6H_5COCH_2C_6H_5$	1.76	0.10	1.79
$C_6H_5COCH(C_6H_5)_2$	1.15	0.16	1.16
$CH_3COC_6H_5-2,4,6-(CH_3)_2$	0.95	0.94	0.92

Grignard and Blanchon⁹⁸ investigated the "enolization" of cyclohexanone by isopropylmagnesium bromide in ethyl ether, and believed that they had isolated the enolate and even the enol. This, however, was contradicted by Kohler and Thompson,⁹⁹ who repeated the experiment and obtained cyclohexanol (68 percent) and 2-cyclohexylidenecyclohexanone (26 percent). Their comment, however, somewhat overstepped the facts in the case. "Grignard reagents containing secondary and tertiary hydrocarbon residues frequently act as condensing and reducing agents, but we can find no evidence that they are more effective than others in inducing enolization, and we also fail to find any evidence that any Grignard reagents can convert mono ketones into enolates unless the hindrance to addition is prohibitive."

Apparently Kohler and Thompson either did not at that time recognize the relationship between enolization and condensation or expressed their true meaning ambiguously.

In the paper just cited, Grignard and Blanchon also reported the "enolization" of di-*n*-butyl ketone by a series of aliphatic Grignard reagents. As no attempt was made to distinguish between gases evolved through enolization and gases arising from reduction, their data are not here reproduced. The non-reducing methylmagnesium iodide and bromide effected 7.5 percent and 6.9 percent enolization, respectively, in ethyl ether solution at 13-14°.

The necessity of using a non-reducing Grignard reagent (preferably methylmagnesium bromide or chloride), or of otherwise taking account of reduction, in investigations of this kind is illustrated by the studies of Blatt and Stone¹⁰⁰ (Table VI-VIII) and of Whitmore and George¹⁰¹ (Table VI-IX).

⁹⁸Grignard and Blanchon, *Bull. soc. chim.*, [4], 49, 23-42 (1931).

⁹⁹Kohler and Thompson, *J. Am. Chem. Soc.*, 55, 3822-33 (1933).

¹⁰⁰Blatt and Stone, *J. Am. Chem. Soc.*, 54, 1495-9 (1932).

¹⁰¹Whitmore and George, *J. Am. Chem. Soc.*, 64, 1239-42 (1942).

TABLE VI-VIII

REACTIONS OF *n*-PROPYL AND ISOPROPYLMAGNESIUM BROMIDES
WITH VARIOUS *n*-PROPYL AND ISOPROPYL KETONES

Ketone	RMgX	Add'n (%)	Red'n (%)	Enol'n (%)	Total (%)
(<i>n</i> -C ₃ H ₇) ₂ CO	<i>n</i> -C ₃ H ₇ MgBr	54	24	...	78
(<i>n</i> -C ₃ H ₇) ₂ CO	<i>i</i> -C ₃ H ₇ MgBr	44	5	15	64*
<i>n</i> -C ₃ H ₇ CO- <i>i</i> -C ₃ H ₇	<i>n</i> -C ₃ H ₇ MgBr	63	17	...	80
<i>n</i> -C ₃ H ₇ CO- <i>i</i> -C ₃ H ₇	<i>i</i> -C ₃ H ₇ MgBr	17	49	...	66
(<i>i</i> -C ₃ H ₇) ₂ CO	<i>n</i> -C ₃ H ₇ MgBr	43	34	...	77
(<i>i</i> -C ₃ H ₇) ₂ CO	<i>i</i> -C ₃ H ₇ MgBr	0	80	...	80

*Considerable condensation.

TABLE VI-IX

REACTIONS OF VARIOUS GRIGNARD REAGENTS WITH
DIISOPROPYL KETONE

RMgX	Add'n (%)	Red'n (%)	Enol'n (%)	Total (%)
CH ₃ MgBr	95	0	0	95
C ₂ H ₅ MgBr	77	21	2	100
<i>n</i> -C ₃ H ₇ MgBr	36	60	2	98
<i>i</i> -C ₃ H ₇ MgBr	0	65	29	94
<i>i</i> -C ₄ H ₉ MgBr	8	78	11	97
<i>t</i> -C ₄ H ₉ CH ₂ MgCl	4	0	90	94
<i>t</i> -C ₄ H ₉ MgX	...	65	...	...

In view of the facts that enolate formation is commonly recognized as competitive with normal addition, and that the latter reaction appears to be subject to marked steric inhibition, whereas the former, in general, is not (as witness the behavior of the mesityl ketones), Whitmore and Lester¹⁰² have studied the interactions of some dineopentylmethyl ketones with several Grignard reagents. Methyl dineopentylmethyl ketone was enolized quantitatively by isopropyl-, isobutyl-, and *t*-butylmagnesium halides. Ethyl dineopentylmethyl ketone reacted similarly with *t*-butylmagnesium chloride. That enolization may, in special cases, be sterically inhibited is suggested by their finding that the phenyl, *o*-tolyl, and *p*-tolyl dineopentylmethyl ketones underwent quantitative addition when treated with methylmagnesium bromide in the "Grignard machine." Presumably the only labile *alpha* hydrogen atom present in these ketones is sterically hindered by the two neopentyl groups.

The results of some "Grignard machine" studies by Whitmore *et al.*^{103,104,105} and Kadesch¹⁰⁶ on the competition between the enolization and addition reactions of methylmagnesium halides with ketones are

¹⁰²Whitmore and Lester, *J. Am. Chem. Soc.*, 64, 1247-51 (1942).

¹⁰³Whitmore and Randall, *J. Am. Chem. Soc.*, 64, 1242-6 (1942).

¹⁰⁴Whitmore and Block, *J. Am. Chem. Soc.*, 64, 1619-21 (1942).

¹⁰⁵Whitmore and Lewis, *J. Am. Chem. Soc.*, 64, 2964-6 (1942).

¹⁰⁶Kadesch, *J. Am. Chem. Soc.*, 66, 1207-13 (1944).

TABLE VI-X
COMPETITIVE ENOLIZATION AND ADDITION REACTIONS OF
METHYLMAGNESIUM HALIDES WITH KETONES

Ketone	Enol'n (%)	Add'n (%)	Reference
CH ₃ COCH ₂ - <i>t</i> -C ₄ H ₉	0	100	W. and L. ¹⁰⁵
CH ₃ COCH(CH ₃) ₂	0	100	W. and B. ¹⁰⁴
CH ₃ COC(CH ₃) ₃	5	86	W. and L. ¹⁰⁵ W. and B. ¹⁰⁴
CH ₃ CO- <i>s</i> -C ₄ H ₉	32	...	W. and B. ¹⁰⁴
C ₂ H ₅ COCH(CH ₃) ₂	0	100	W. and B. ¹⁰⁴
CH ₃ COC(CH ₃) ₂ C ₂ H ₅	14	74	W. and L. ¹⁰⁵
C ₂ H ₅ COC(CH ₃) ₃	9	86	W. and B. ¹⁰⁴
CH ₃ COC ₆ H ₅	9	76	K. ¹⁰⁶
CH ₃ COC(C ₂ H ₅) ₂ CH ₃	84	0	W. and L. ¹⁰⁵
CH ₃ COCH(CH ₃)- <i>t</i> -C ₄ H ₉	48	47	W. and B. ¹⁰⁴
<i>n</i> -C ₃ H ₇ CO- <i>s</i> -C ₄ H ₉	53	40	W. and B. ¹⁰⁴
<i>i</i> -C ₃ H ₇ CO- <i>t</i> -C ₄ H ₉	0	49	W. and B. ¹⁰⁴
1-Indanone	12	97	K. ¹⁰⁶
CH ₃ COC ₆ H ₄ -2-CH ₃	14	58	K. ¹⁰⁶
CH ₃ COC(C ₂ H ₅) ₃	94	0	W. and L. ¹⁰⁵
C ₂ H ₅ COCH(CH ₃)- <i>t</i> -C ₄ H ₉	62	33	W. and B. ¹⁰⁴
1-Tetralone	17	57	K. ¹⁰⁶
CH ₃ COC ₆ H ₃ -2,4-(CH ₃) ₂	19	55	K. ¹⁰⁶
H ₂ C=CHCOC(C ₂ H ₅) ₃	0	58	W. and L. ¹⁰⁵
<i>t</i> -C ₄ H ₉ COCH(C ₂ H ₅) ₂	5	19	W. and B. ¹⁰⁴
HOCH ₂ CH ₂ COC(C ₂ H ₅) ₃	58	27	W. and L. ¹⁰⁵
CH ₃ CO-1-C ₁₀ H ₇	6	74	K. ¹⁰⁶
CH ₃ CO-2-C ₁₀ H ₇	15	117	K. ¹⁰⁶
4,7-Dimethyl-1-indanone	21	67	K. ¹⁰⁶
5,7-Dimethyl-1-indanone	16	66	K. ¹⁰⁶
Benzosuberone*	25	61	K. ¹⁰⁶
CH ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	73	...	K. ¹⁰⁶
1-Acetyl-2-methylnaphthalene	102	0	K. ¹⁰⁶
5,8-Dimethyl-1-tetralone	17	60	K. ¹⁰⁶
CH ₃ COC ₆ H-2,3,5,6-(CH ₃) ₄	81	0	K. ¹⁰⁶
<i>i</i> -C ₄ H ₉ COC(C ₂ H ₅) ₃	85	0	W. and L. ¹⁰⁵
6,9-Dimethylbenzosuberone†	101	0	K. ¹⁰⁶
4-Methyl-7-isopropyl-1-indanone	22	51	K. ¹⁰⁶
CH ₃ COC(CH ₃)(<i>t</i> -C ₄ H ₉)CH ₂ - <i>t</i> -C ₄ H ₉	94	0	W. and R. ¹⁰³
C ₂ H ₅ COC(CH ₃)(<i>t</i> -C ₄ H ₉)CH ₂ - <i>t</i> -C ₄ H ₉	57	0	W. and R. ¹⁰³
<i>i</i> -C ₃ H ₇ COC(CH ₃)(<i>t</i> -C ₄ H ₉)CH ₂ - <i>t</i> -C ₄ H ₉	25	0	W. and R. ¹⁰³

*5-Oxobenzosuberone; 5-oxo-5,6,8,9-tetrahydro-7H-cycloheptabenzenone.

†1,4-Dimethyl-5-oxobenzosuberone.

assembled in Table VI-X. Whereas the halide used and other experimental details vary from study to study, the data of the various studies are not strictly comparable one with another.

A similar "Grignard machine" study of the reactions of methylmagnesium iodide with various more or less "hindered" ketones, by Smith and Guss¹⁰⁷ is summarized in Table VI-XI.

¹⁰⁷Smith and Guss, *J. Am. Chem. Soc.*, 59, 804-6 (1937).

TABLE VI-XI

COMPETITIVE ENOLIZATION AND ADDITION REACTIONS OF
METHYLMAGNESIUM IODIDE WITH SEVERAL ACETYL
AND DIACETYL METHYLATED BENZENES

<u>Ketone</u>	<u>"Active" H</u>	<u>Addition</u>
Acetophenone	0.025	1.025
Aceto- <i>m</i> -xylene	0.05	1.02
Acetomesitylene	1.03	0.00
5-Acetopseudocumene	0.25	0.79
Acetodurene	0.97	0.04
Acetoisodurene	0.94	0.07
Acetoprehnitene	0.75	0.27
Acetopentamethylbenzene	0.93	0.01
Diaceto- <i>m</i> -xylene	0.16	1.82
Diacetomesitylene	1.82	0.26
Diacetopseudocumene	1.66	0.44
Diacetodurene	1.62	0.54
Diacetoisodurene	1.72	0.48
Diacetoprehnitene	1.68	0.46

The enolization of various cyclic diketones has been investigated by Koelsch *et al.*¹⁰⁸

That the Grignard reagent does not simply react with enol present, but that it actually converts ketone to enolate is readily seen by comparison

TABLE VI-XII

ENOL CONTENT OF SEVERAL KETONES AS ESTIMATED
BY C_2H_5ZnI REACTION

<u>Ketone</u>	<u>% Enol</u>
$(CH_3)_2CO$	0
$(n-C_3H_7)_2CO$	0
$(n-C_4H_9)_2CO$	0
$(C_6H_5CH_2)_2CO$	0
$CH_3COC_6H_5$	0
$(CH_2)_4CO$	0
$(CH_2)_5CO$	8.2
4-Methylcyclohexanone	6.3
Menthone*	0
Carvone†	0
Thujone‡	0
$[(CH_3)_2C=CH]_2CO$	6.3

*3-Methyl-6-isopropylcyclohexanone.

†2-Methyl-5-isopropenyl-2-cyclohexen-1-one.

‡2-Methyl-5-isopropylbicyclo[3.1.0]hexan-3-one.

¹⁰⁸(a) Koelsch, *J. Am. Chem. Soc.*, 58, 1321-4 (1936); (b) Koelsch and Geissman, *J. Org. Chem.*, 3, 480-8 (1939); (c) Koelsch and Wawzonek, *ibid.*, 6, 684-9 (1941).

of Grignard enolization data with percentage enol content determined by one of the standard methods.¹⁰⁹

On the assumption, not completely justified, that enolization by ethylzinc iodide is very slow as compared with the reaction of that reagent with the enol form of a ketone, Grignard and Blanchon (*loc. cit.*⁹⁸) employed the method of Job and Reich (*loc. cit.*⁹⁴) to determine the enol content of several ketones. Their data are presented in Table VI-XII.

TABLE VI-XIII

ENOL CONTENT OF SEVERAL KETONES AS ESTIMATED
BY MEYER'S BROMINATION METHOD

<u>Ketone</u>	<u>% Enol</u>
$\text{CH}_3\text{COCH}_2\text{CO}_2\text{CH}_3$	4.1
$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	7.7
$\text{CH}_3\text{COCH}(\text{CH}_3)\text{CO}_2\text{CH}_3$	3.2
$\text{CH}_3\text{COCHBrCO}_2\text{C}_2\text{H}_5$	4.0
$\text{C}_6\text{H}_5\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	31.9
$\text{C}_6\text{H}_5\text{COCH}_2\text{CO}_2\text{CH}_3$	16.3
$(\text{H}_5\text{C}_2\text{O}_2\text{CCH}_2)_2\text{CO}$	16.8
$(\text{CH}_3\text{CO})_2\text{CH}_2$	80.4
$\text{CH}_3\text{COCH}_2\text{COC}_6\text{H}_5$	98.6
$(\text{C}_6\text{H}_5\text{CO})\text{CH}_2$	102.0

TABLE VI-XIV

ENOL CONTENT OF SEVERAL KETONES AS ESTIMATED BY
SCHWARZENBACH'S MODIFICATION OF MEYER'S
BROMINATION METHOD

<u>Ketone</u>	<u>% Enol</u>
$(\text{CH}_3\text{CO})_2\text{CH}_2$	15.5
$(\text{CH}_3\text{CO})_2\text{CHBr}$	8.1
$(\text{CH}_3\text{CO})_2\text{CHCH}_3$	2.8
$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	0.38
2-Acetylcyclohexanone	29.1
2-Acetylcyclopentanone	15.1
1,3-Indandione	1.6
2-Methyl-1,3-indandione	1.03
Dimedon*	95.3
1,2-Cyclohexanedione	100
3-Methyl-1,2-cyclohexanedione	100
1,2-Cyclopentanedione	100
3-Methyl-1,2-cyclopentanedione	100
α -Oxo- β -methylbutyrolactone	100
$(\text{CH}_3)_2\text{CO}$	2.5×10^{-4}
$(\text{CH}_3\text{CO})_2$	5.6×10^{-3}
$(\text{CH}_2)_4\text{CO}$	4.8×10^{-3}
$(\text{CH}_2)_5\text{CO}$	2×10^{-2}

* 5,5-Dimethyl-1,3-cyclohexanedione.

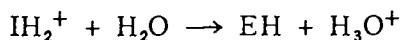
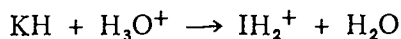
¹⁰⁹For references to methods of determining enol content, see: Schwarzenbach and Felder, *Helv. Chim. Acta*, 27, 1044-60 (1944). See also: Knorr, *Ber.*, 44, 2772-8 (1911).

Several determinations by the classical bromination method of Meyer¹¹⁰ are recorded in Table VI-XIII.

Schwarzenbach *et al.*¹¹¹ have elaborated and refined the technique of Meyer to devise a method that is probably the most reliable of the generally applicable methods at present available. Some of their data are collected in Table VI-XIV.

Probable mechanism of Grignard reagent enolate formation. Practically nothing has been demonstrated directly concerning the mechanism of the Grignard reagent enolate formation, doubtless because of its relatively complicated nature. However, the general acid-base-catalyzed enolization of ketones, particularly acetone, has been thoroughly studied and is well understood.¹¹²

The so-called acid-catalyzed enolization in aqueous solution involves two processes: (1) the association of a proton, supplied by any acid present, but predominantly by H_3O^+ , with the oxygen of the ketone carbonyl group to form an intermediate ion; (2) the abstraction from an *alpha* carbon atom of the intermediate ion of a proton by any base present, but predominantly by H_2O . Hammett has formulated these processes as follows:



in which KH represents the ketone, IH_2^+ the intermediate ion, and EH the enol. Of the processes represented, the latter is regarded as the rate-determining step.

The Grignard enolate formation differs from the aqueous "acid-catalyzed" enolization in several important respects, yet, if it be conceded that the transformation may be acid-base-catalyzed in the Lewis as well as in the Brønsted-Lowry sense, a striking parallelism exists. In the Lewis sense, the molecular and ionic species RMgX , R_2Mg , MgX_2 , MgX^+ , and RMg^+ , all of which are present in variously associated and solvated forms in an ethereal Grignard reagent solution, are all acids. Presumably any and all of these might serve as catalyst for the first

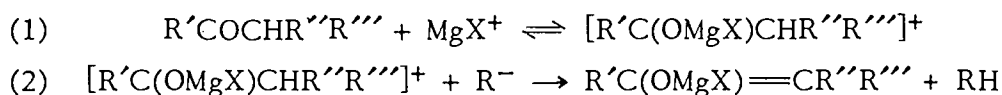
¹¹⁰Meyer, *Ann.*, 380, 212-42 (1911).

¹¹¹Schwarzenbach and Felder, *Helv. Chim. Acta*, 27, 1044-60 (1944); Schwarzenbach and Willwer, *Helv. Chim. Acta*, 30, 656-8, 659-63, 663-9, 669-74 (1947).

¹¹²(a) Dawson *et al.*, *J. Chem. Soc.*, 1926, 2282-96, 2872-8, 3166-73; 1927, 213-22, 458-66, 756-61; 1928, 543-51, 1239-48, 1248-57, 2844-53; 1929, 1217-29, 1884-95, 2530-9; 1930, 79-85, 2180-9; 1931, 2658-65; 1932, 2612-20; (b) Pedersen, *J. Phys. Chem.*, 38, 581-99 (1934); *Trans. Faraday Soc.*, 34, 237-44 (1938); (c) Reitz, *Z. physik. Chem.*, 179A, 119-34 (1937); (d) Zucker and Hammett, *J. Am. Chem. Soc.*, 61, 2779-84, 2785-90, 2791-8 (1939). For an excellent discussion of concerted displacement reactions, including enolizations, consult: Swain, *J. Am. Chem. Soc.*, 72, 4578-83 (1950).

stage* of the transformation by forming an intermediate complex through the oxygen of the ketone carbonyl group. Pursuing the parallelism farther, the bases present, or potentially available for participation in the second stage of the transformation, are R^- , X^- , and Et_2O . It is highly doubtful that the halide ion, X^- , is sufficiently basic to play any significant part. The more basic ether might conceivably abstract a proton and subsequently yield it to the very strongly basic organic ion, R^- , but this, on the whole, appears unlikely because it involves the transfer of a proton from carbon to oxygen. At all events, the reaction by-product isolated in quantitative yield is RH .

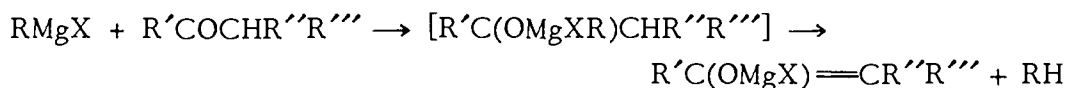
Selecting, for the sake of simplicity, one of the possible acid catalysts and the most probable of the basic reactants, the transformation may be represented as follows:



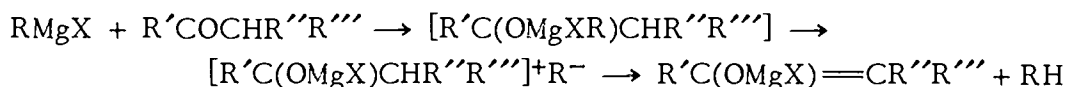
This is essentially the scheme proposed by Arnold *et al.*¹¹³

Because the reaction $R^- + H^+ \rightarrow RH$ is irreversible, R^- , and its source, $RMgX$, become participants in the reaction and hence are not "catalysts" in the commonly accepted definition of the term. Nevertheless, the likeness of this irreversible enolate formation to "acid-catalyzed" enolization is obvious.

There remains to be considered as a possible mechanism of reaction a process (or series of processes) essentially that suggested by Bredt-Savelsburg¹¹⁴, and accepted by Grignard¹¹⁵ himself, namely the association of a molecule of ketone with a molecule of Grignard reagent to form an intermediate complex, and the subsequent decomposition of the complex to yield enolate and hydrocarbon.



Actually, there is no significant difference between the two mechanisms proposed, for if we attempt to represent either of them in greater detail, we arrive at a sequence somewhat like the following:



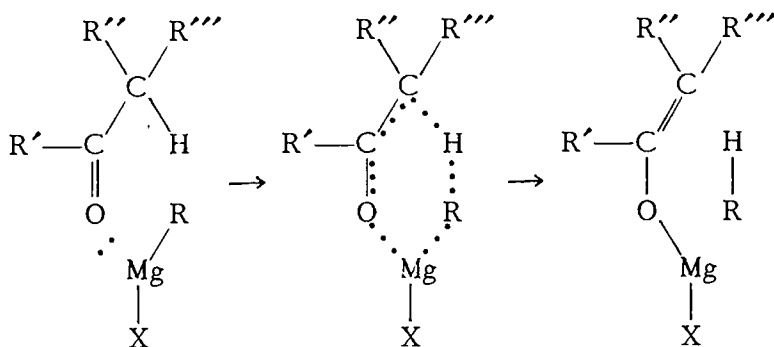
* The reaction is divided into "first" and "second" stages for the sake of convenience in discussion; it may well be, and probably is, of the concerted displacement type.

¹¹³Arnold, Bank, and Liggett, *J. Am. Chem. Soc.*, 63, 3444-6 (1941).

¹¹⁴Bredt-Savelsburg, *J. prakt. Chem.*, [2], 107, 65-85 (1924).

¹¹⁵Grignard and Savard, *Bull. soc. chim. Belg.*, 36, 97-107 (1927); Grignard and Blanchon, *Bull. soc. chim.*, [4], 49, 23-42 (1931).

Although ionic formulae are convenient adjuncts to the elucidation of the ideas here proposed, actual dissociation of the ions represented is not necessarily implied. Neither is there any compulsion to assume that the fundamental processes specified in equations 1 and 2 are consecutive rather than simultaneous. A conceivable mechanism embodying the concept of a quasi six-membered ring transition state might be represented as follows:



This is essentially the scheme proposed by Lutz and Kibler.¹¹⁶

It should be emphasized, of course, that, for the sake of convenience, all these equations are over-simplified (see Chapter IV, Constitution and Dissociation of the Grignard Reagent).

It may not be amiss, either, to call to the reader's attention the fact that in supposedly quantitative studies the amount of Grignard enolization observable may be markedly affected by metallic impurities (notably iron) present in the magnesium used for reagent preparation. For example, it has been observed at the University of Chicago^{116,1} that, whereas methylmagnesium bromide prepared from sublimed magnesium undergoes rapid "normal" addition to isophorone (3,3,5-trimethyl-2-cyclohexen-1-one) without detectable enolization (*i.e.*, methane evolution), the presence of as little as one mole percent of ferric bromide leads to the production of a reaction mixture which, upon treatment with benzoyl chloride, yields appreciable quantities of the enol benzoate.

GRIGNARD CONDENSATIONS OF ALDEHYDES AND KETONES

Grignard¹¹⁷ himself noted that the interaction of acetone and isoamylmagnesium bromide leads to the formation, not only of the expected tertiary alcohol (in 46 percent yield), but also of small amounts of mesityl oxide $[(CH_3)_2C=CHCOCH_3]$ and phorone $[(CH_3)_2C=CHCOCH=C(CH_3)_2]$.

Carre¹¹⁸ reported that, from the treatment of *o*-methylbenzylmagnesium bromide with acetone, he obtained only meagre (*ca.* 1 percent) yields of

¹¹⁶Lutz and Kibler, *J. Am. Chem. Soc.*, 62, 360-72 (1940).

^{116,1}Kharasch and Tawney, *J. Am. Chem. Soc.*, 63, 2308-15 (1941); Kharasch, Rowe, and Ordas, unpublished work.

¹¹⁷Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).

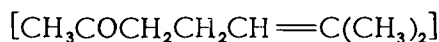
¹¹⁸Carre, *Bull. soc. chim.*, [4], 5, 486-9 (1909).

the tertiary alcohol, together with considerable amounts of condensation products, principally phorone.

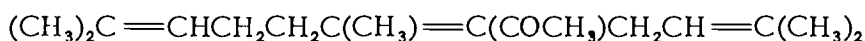
Upon treatment of isopropylmagnesium iodide with cyclopentanone, Meisenheimer¹¹⁹ obtained a 16 percent yield of the "normal" product, but found the principal product to be 2-cyclopentylidenecyclopentanone.

From butanone and isopropylmagnesium bromide, Pariselle and Simon¹²⁰ obtained the expected tertiary alcohol and 5-methyl-4-hepten-3-one in approximately equivalent amounts (*ca.* 25 percent).

According to Grignard and Escourru¹²¹, the *beta* isomer

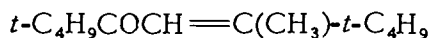


of the natural methylheptenone mixture reacts with isopropyl-, *n*-butyl-, and isoamylmagnesium halides to form the corresponding tertiary alcohols in varying yields. In most cases, a ketonic byproduct with analysis corresponding to the empirical formula $\text{C}_{12}\text{H}_{26}\text{O}$ is also obtained. This is believed to be the dehydrated ketol,



From the treatment of 3-pentanone with *t*-butylmagnesium chloride, and of pinacolone ($\text{CH}_3\text{CO}-t\text{-C}_4\text{H}_9$) with isopropylmagnesium bromide or *t*-butylmagnesium chloride, Conant and Blatt¹²² obtained condensation products not specifically characterized.

Tolstopyatov¹²³ found that, with methylmagnesium bromide or iodide, pinacolin yields about 90 percent of the "normal" product, about 6 percent of the ketol, and somewhat less of the dehydrated ketol,



According to Esafov¹²⁴, mesityl oxide $[\text{CH}_3\text{COCH}=\text{C}(\text{CH}_3)_2]$ yields with ethylmagnesium bromide very little of the "normal" product, the principal reaction being the formation of high-boiling condensation products. With both mesityl oxide and furfurylideneacetone, phenylmagnesium bromide yields high-boiling condensation products only.

Whitmore *et al.*¹²⁵ report that methyl isopropyl ketone yields with *t*-butylmagnesium chloride [in addition to 46 percent recovered ketone (from the enolate), 29 percent secondary alcohol (from ketone reduction), isobutylene, and isobutane] 18 percent of the ketol. With isoamylmagnesium chloride, the products isolated were recovered ketone (2.4 percent),

¹¹⁹Meisenheimer, *Ann.*, 405, 129-75 (1914).

¹²⁰Pariselle and Simon, *Compt. rend.*, 173, 86-9 (1921).

¹²¹Grignard and Escourru, *Compt. rend.*, 176, 1860-3 (1923).

¹²²Conant and Blatt, *J. Am. Chem. Soc.*, 51, 1227-36 (1929).

¹²³Tolstopyatov, *J. Russ. Phys.-Chem. Soc.*, 62, 1813-28 (1930); *Chem. Abstr.*, 25, 3959 (1931); *Chem. Zentr.*, 1931, I, 2738.

¹²⁴Esafov, *J. Gen. Chem. (U.S.S.R.)*, 9, 467-70 (1939); *Chem. Abstr.*, 33, 9282 (1939).

¹²⁵Whitmore, Whitaker, Breivik, Wheeler, Miner, and Sutherland, *J. Am. Chem. Soc.*, 63, 643-54 (1941).

secondary alcohol (49.0 percent), and ketol dehydration product (35.6 percent).

From pinacolone and *t*-butylmagnesium chloride, Hickinbottom and Schlüchterer¹²⁶ obtained, in addition to secondary alcohol, the ketol and its dehydration product.

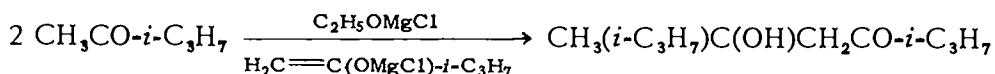
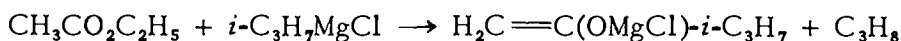
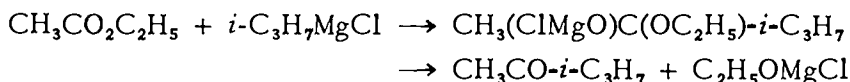
In general, whether the ketol or its dehydration product is obtained depends upon the method of recovery. Often, it is more convenient to isolate the dehydration product.

Relatively little lucid discussion of the condensation side-reaction has appeared in the periodical literature, possibly for the reason that many workers have regarded the fundamental facts as too obvious to justify elaboration.

Grignard undoubtedly recognized these reactions as typical "base-catalyzed" ketolizations, and he demonstrated, with Dubien,¹²⁷ and with Fluchaire¹²⁸ that aldehyde aldolization, ketone ketolization, and cross-condensation between aldehydes and ketones may be brought about by a variety of ROMgX compounds. (See also the work of Grignard and Colonge¹²⁹ on similar condensations effected with the aid of RNHMgX and RR'NMgX compounds.)

Tolstopyatov (*loc. cit.*¹²³) suggested that, in the interaction between methylmagnesium halide and pinacolone, the condensing agent is *t*-C₄H₉(CH₃)₂COMgX.

Ivanoff and Spassoff,¹³⁰ who detected among the products of reaction of ethyl acetate with isopropylmagnesium chloride, the ketol of the ketone which would presumably be formed in the first stage of reaction of the ester with the Grignard reagent, accounted for its presence as follows:*



In a sequel¹³¹ to the paper cited, they expressed the opinion that the most probable ketolization agents are the halomagnesium salts of the enol and of the ketol which are found in the reaction medium, and reasoned that a good enolizing reagent is indirectly a good condensing agent. On

¹²⁶Hickinbottom and Schlüchterer, *Nature*, 155, 19 (1945).

¹²⁷Grignard and Dubien, *Compt. rend.*, 177, 299-302 (1923).

¹²⁸Grignard and Fluchaire, *Ann. chim.*, [10], 9, 5-54 (1928).

¹²⁹(a) Grignard and Colonge, *Compt. rend.*, 194, 929-33 (1932); (b) Colonge, *ibid.*, 196, 1414-6 (1933); (c) Colonge, *Bull. soc. chim.*, [5], 1, 1101-14 (1934).

¹³⁰Ivanoff and Spassoff, *Bull. soc. chim.*, [5], 2, 816-24 (1935).

* See discussion of apparent ester enolization, Chapter VIII.

¹³¹Ivanoff and Spassoff, *Bull. soc. chim.*, [5], 2, 1435-8 (1935).

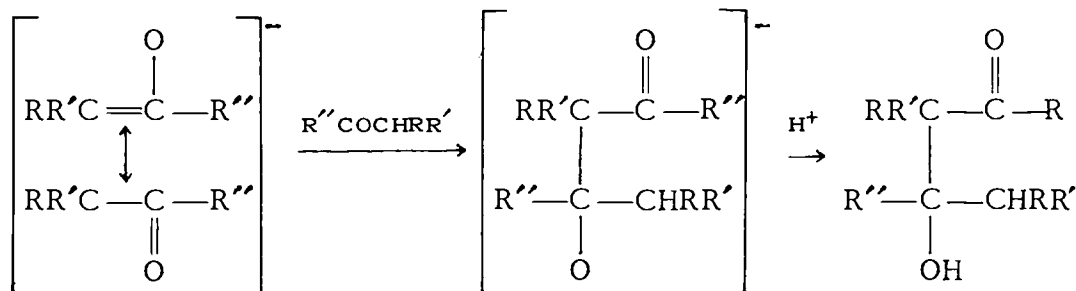
this basis, they planned the ketolization study the results of which are summarized in Table VI-XV.

TABLE VI-XV
KETOLIZATION THROUGH THE AGENCY OF GRIGNARD REAGENTS

Ketone	Grignard Reagent	Yield of Ketol (%)
$\text{CH}_3\text{CO}-i\text{-C}_3\text{H}_7$	$i\text{-C}_3\text{H}_7\text{MgCl}$	70
	$s\text{-C}_4\text{H}_9\text{MgBr}$	37
	$t\text{-C}_4\text{H}_9\text{MgCl}$	50
$\text{CH}_3\text{CO}-t\text{-C}_4\text{H}_9$	$i\text{-C}_3\text{H}_7\text{MgCl}$	43
	$s\text{-C}_4\text{H}_9\text{MgBr}$	45
	$t\text{-C}_4\text{H}_9\text{MgCl}$	48
$(\text{CH}_2)_4\text{CO}$	$i\text{-C}_3\text{H}_7\text{MgCl}$	36
	$s\text{-C}_4\text{H}_9\text{MgCl}$	42
$(\text{CH}_2)_5\text{CO}$	$i\text{-C}_3\text{H}_7\text{MgCl}$	15

On the basis of a rather superficial survey of the literature (if one may judge by their bibliography), Hickinbottom and Schlüchterer (*loc. cit.*¹²⁶) offer the following contribution. "The experimental data at present available leads [*sic*] to the conclusion that alkylmagnesium halides with highly branched chains not only bring about reduction of the ketone, but also promote condensation. The structure of the ketone is also an important factor; those with an available hydrogen adjacent to the carbonyl and a slow rate of reaction toward Grignard reagents condense more readily. If they react with Grignard reagents which do not cause reduction, such as the arylmagnesium halides, the formation of the condensation is still more favored."

According to the commonly accepted present-day view, the essential step in self-ketolization is the addition of an enolate ion to the carbon member of the carbonyl double bond of a molecule of the corresponding keto form.



Necessarily, therefore, only enolizable ketones may be expected to self-ketolize, and the enolate may be regarded as a reactant rather than a "ketolization agent." It further follows that enolization may itself become a competing reaction, for ketones which enolize extremely readily, or which undergo addition with difficulty (*e.g.*, actomesitylene), cannot be expected to ketolize appreciably for lack of the necessary reactive

keto molecules. Note, however, that cross-condensation is not necessarily precluded. This is doubtless one reason why the enolate of acetomesitylene is said to react with benzaldehyde like a "true Grignard reagent of the formula $C_9H_{11}COCH_2MgBr$."¹³²

Whether the participant enolate ions arise through the agency of some "base," such as $NaOH$, $ROMgX$ or $RR'NMgX$, through direct attack of the Grignard reagent upon an enol, or through Grignard enolization of a ketone, is immaterial.

Whenever any appreciable amount of enolate is present, the keto form remaining is subject to several competing reactions, among them: (1) further enolization; (2) condensation with enolate ions; (3) "normal" Grignard reagent addition; and, in cases where the Grignard reagent is also a reducing agent, (4) reduction. In the first two of these reactions, the nature of the ketone itself is the primary determinant of rates; in the latter two, the natures of both ketone and Grignard reagent are significant. To predict the total outcome of any given situation complicated by so many rates of competing reactions, which, in turn, are determined by more or less independent properties of each of two reactants, by means of concise generalizations is manifestly impossible. Nevertheless, given a specific Grignard reagent-ketone pair, the experienced operator may make qualitative predictions with considerable confidence.

Reports of aldehyde condensations have been rarer than reports of ketone condensations, in part, perhaps, because of the greater average reactivity of aldehyde carbonyl groups with respect to "normal" Grignard reagent addition.

Faworsky¹³³ reported, without revealing any experimental details, that, in the preparation of isopropyl-*t*-butylmethanol from isobutyraldehyde and *t*-butylmagnesium chloride, he obtained yields of about 25 percent of the secondary alcohol, 50 percent of isobutyl alcohol, and 25 percent of 2,2,4-trimethylpentane-1,3-diol (the reduction product of the aldol). Under the conditions employed by them, Conant and Blatt (*loc. cit.*¹²²), however, were unable to detect any glycol among the products of this reaction.

Vanine¹³⁴ reported that the products of interaction of isobutylmagnesium bromide and *n*-heptaldehyde are the secondary alcohol, "aldehyde polymer," and an alcohol of the empirical formula $C_{12}H_{26}O$.

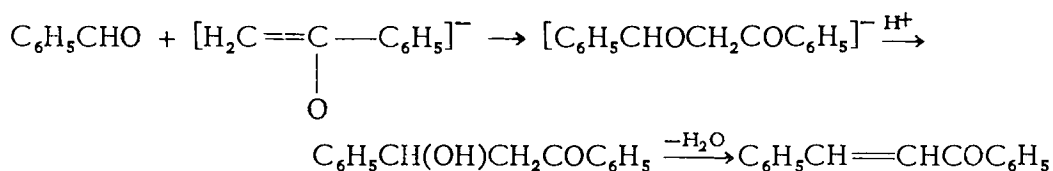
Occasionally, an aldehyde participates in a secondary condensation. For example, Marshall¹³⁵ found, among the products of reaction of excess benzaldehyde and methylmagnesium iodide, phenyl styryl ketone (which he incorrectly characterized as "methyldeoxybenzoïn").

¹³²Fuson, Fugate, and Fisher, *J. Am. Chem. Soc.*, 61, 2362-5 (1939).

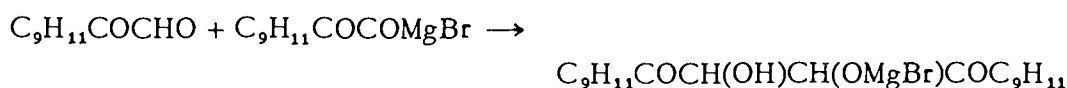
¹³³Faworsky, *J. prakt. Chem.*, [2], 88, 641-98 (1913).

¹³⁴Vanine, *J. Russ. Phys.-Chem. Soc.*, 47, 1094-1101 (1915); *Bull. soc. chim.*, [4], 20, 495 (1916).

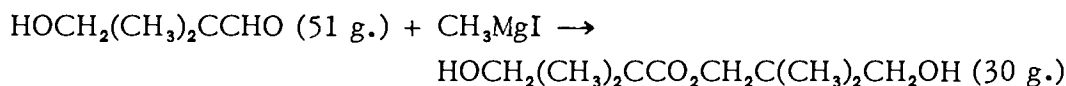
¹³⁵Marshall, *J. Chem. Soc.*, 105, 527-34 (1914); 107, 509-23 (1915).



The α,β -dimesitoylethylene glycol of Gray and Fuson¹³⁶ is probably also the result of a secondary condensation.



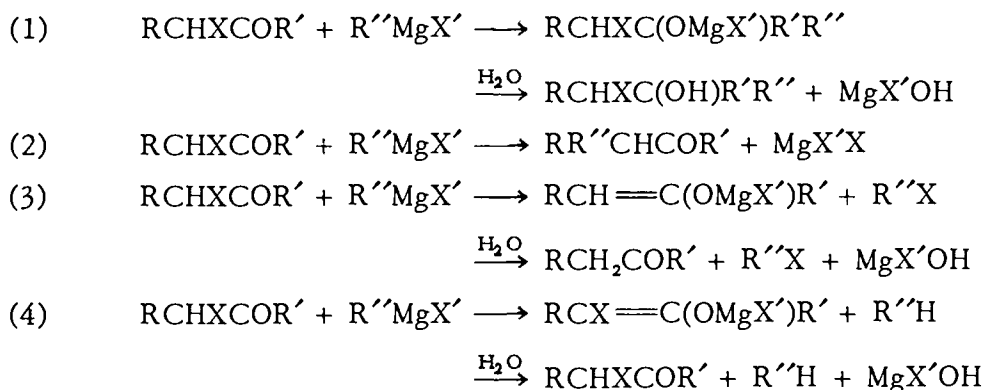
A different type of "condensation" has been reported by Franke and Kuhn.¹³⁷



This represents a special case of the Tichtchenko¹³⁸ reaction, which may be regarded as a variation of the Cannizzaro reaction. In their study of the action of ROMgX compounds on aldehydes, Grignard and Fluchaire (*loc. cit.*¹²⁸) found that aldolization is usually accompanied by the Cannizzaro-Tichtchenko oxidation-reduction-condensation.

α -HALO KETONES AND ALDEHYDES*

Saturated α -halo ketones undergo with Grignard reagents (one equivalent) four types of reactions, namely: (1) normal addition at the carbonyl double bond to give a tertiary alcoholate; (2) replacement of the *alpha* halogen atom by the organic radical of the Grignard reagent; (3) formation of the enolate of the corresponding non-halogenated ketone; and (4) formation of the enolate of the α -halogenated ketone.



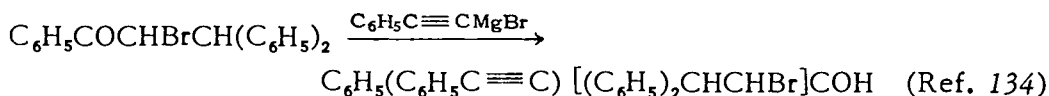
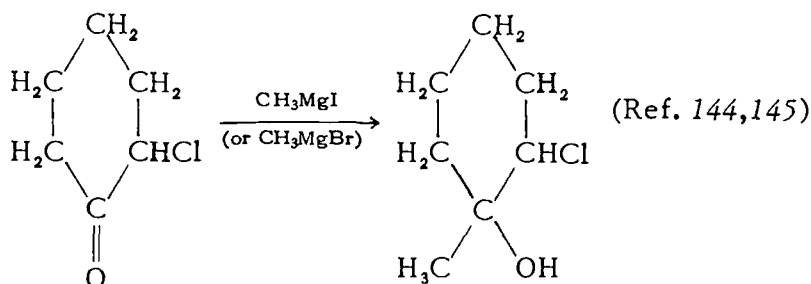
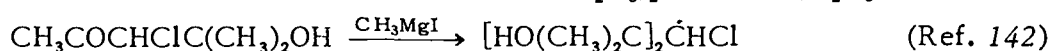
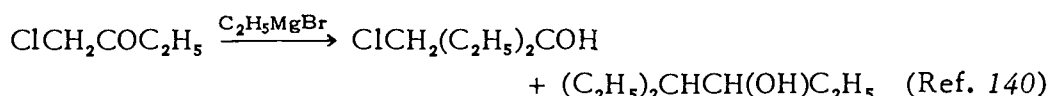
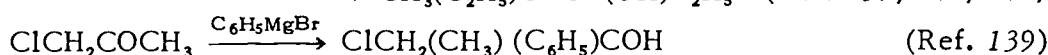
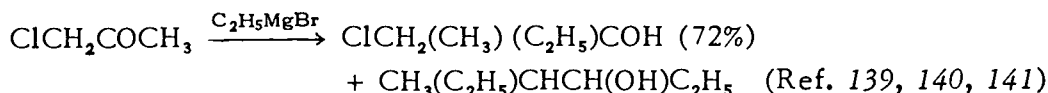
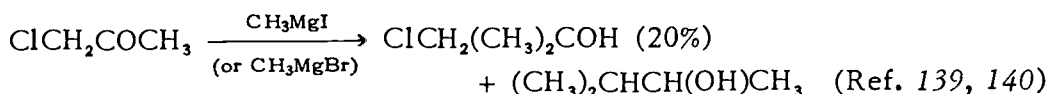
¹³⁶Gray and Fuson, *J. Am. Chem. Soc.*, 56, 739-41 (1934).

¹³⁷Franke and Kuhn, *Monatsh.*, 25, 865-70 (1904).

¹³⁸Tichtchenko, *J. Russ. Phys.-Chem. Soc.*, 38, 355-419, 482-520 (1906); *Bull. soc. chim.*, [4], 4, 982, 1121 (1908).

*The reactions of organomagnesium derivatives with α -chlorocyclanones have been reviewed by Tiffeneau, *Bull. soc. chim.*, [5], 12, 621-7 (1945).

"Normal" addition. The first of these reactions takes place when there is little hindrance, steric or otherwise, to normal addition, and when the halomagnesium halohydrinate so formed is stable under the reaction conditions imposed. Examples have been reported by Fourneau,¹³⁹ by Fourneau and Tiffeneau,¹⁴⁰ by Kyriakides,¹⁴¹ by Pastereau and Bernard,¹⁴² by Bartlett and Rosenwald,¹⁴³ by Tiffeneau and Tchoubar,¹⁴⁴ and by Kohler and Tishler.¹⁴⁵



Halogen-radical exchange. Reactions in which the *alpha* halogen atom of a ketone is replaced by the organic radical of the Grignard reagent have been reported by Bouveault and Chereau,¹⁴⁶ by Tiffeneau,¹⁴⁷ by Vavon

¹³⁹Fourneau, *Compt. rend.*, 134, 774-5 (1902); *Chem. Zentr.*, 1902, I, 1092.

¹⁴⁰Fourneau and Tiffeneau, *Compt. rend.*, 145, 437-9 (1907); *Chem. Zentr.*, 1907, II, 1320.

¹⁴¹Kyriakides, *J. Am. Chem. Soc.*, 36, 657-63 (1914).

¹⁴²Pastereau and Bernard, *Compt. rend.*, 174, 1555-7 (1922); *Chem. Abstr.*, 16, 2842 (1922).

¹⁴³Bartlett and Rosenwald, *J. Am. Chem. Soc.*, 56, 1990-4 (1934).

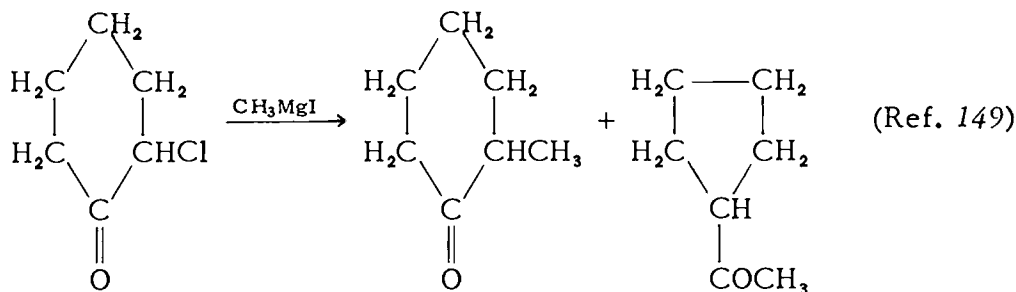
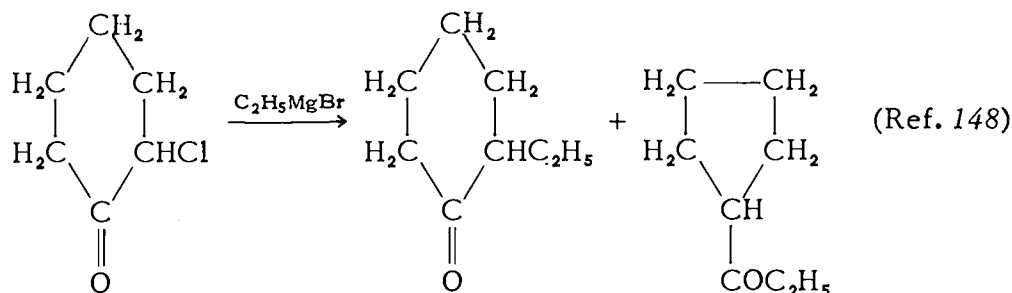
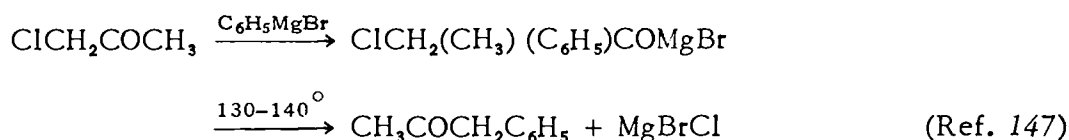
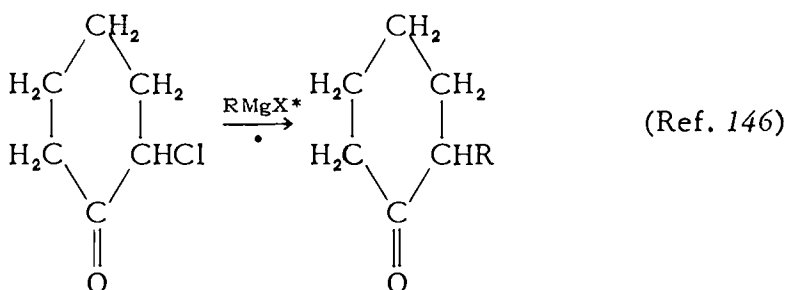
¹⁴⁴Tiffeneau and Tchoubar, *Compt. rend.*, 198, 941-3 (1934).

¹⁴⁵Kohler and Tishler, *J. Am. Chem. Soc.*, 57, 217-24 (1935).

¹⁴⁶Bouveault and Chereau, *Compt. rend.*, 142, 1086-7 (1906); *Chem. Zentr.*, 1906, II, 125.

¹⁴⁷Tiffeneau, *Ann. chim.*, [8], 10, 322-78 (1907).

and Mitchovitch,¹⁴⁸ by Vavon and Perlin-Borrel,¹⁴⁹ by Tiffeneau and Tchoubar,¹⁴⁴ by McKenzie, Roger, and McKay,¹⁵⁰ by Richard,¹⁵¹ by Roger and McGregor,¹⁵² by Mitchovitch,¹⁵³ and by Sackur.¹⁵⁴ A similar replacement of the *alpha* halogen atom of an aldehyde is reported by Tchoubar and Sackur.¹⁵⁵



¹⁴⁸Vavon and Mitchovitch, *Bull. soc. chim.*, [4], 45, 961-72 (1929).

¹⁴⁹Vavon and Perlin-Borrel, *Bull. soc. chim.*, [4], 51, 994 (1932).

¹⁵⁰McKenzie, Roger, and McKay, *J. Chem. Soc.*, 1932, 2597-604.

¹⁵¹Richard, *Compt. rend.*, 198, 1242-4 (1934).

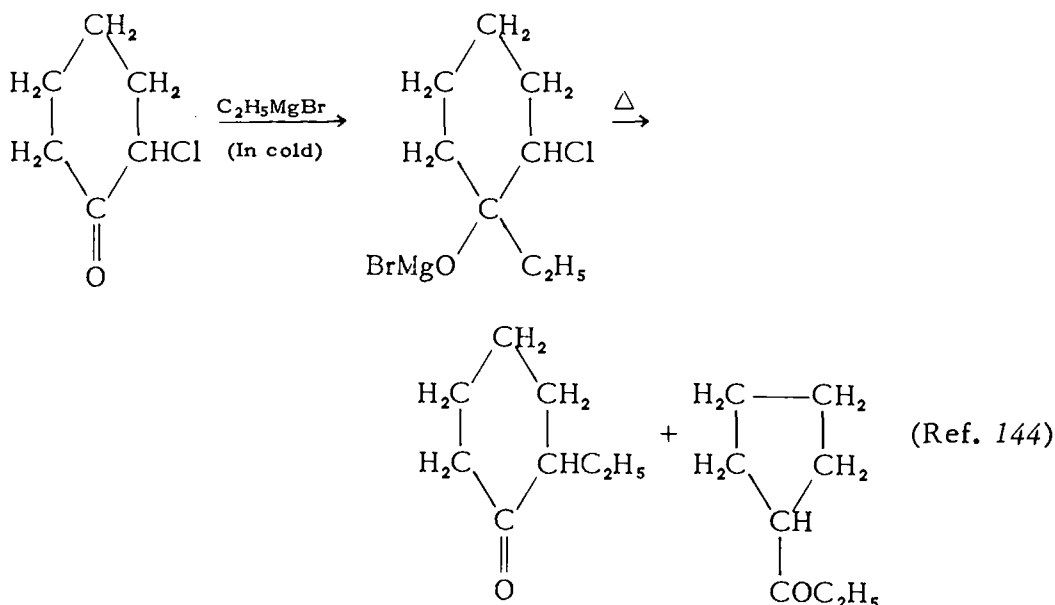
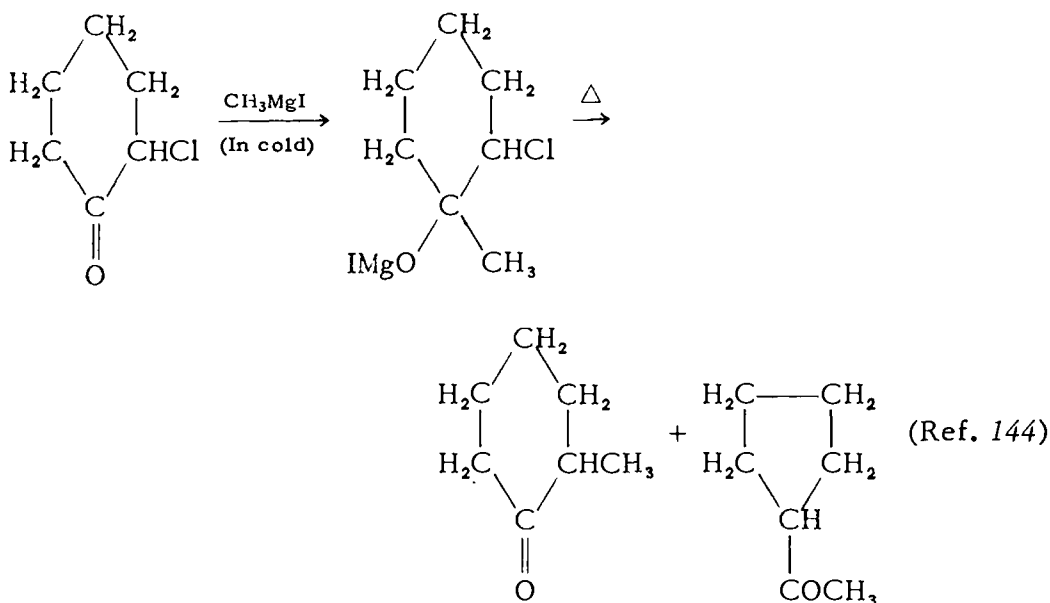
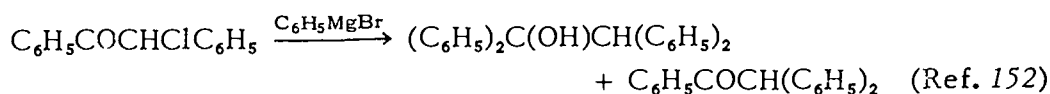
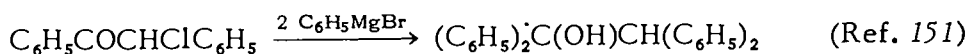
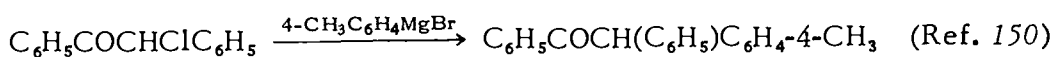
¹⁵²Roger and McGregor, *J. Chem. Soc.*, 1934, 1850-3.

¹⁵³Mitchovitch, *Compt. rend.*, 200, 1601-3 (1935).

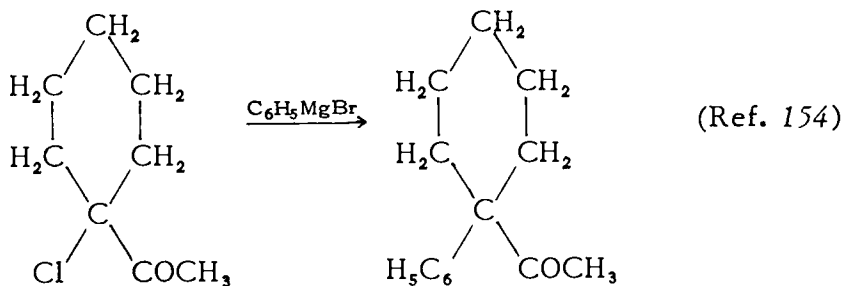
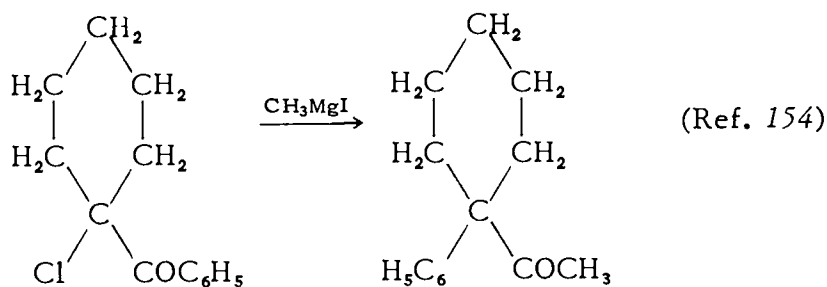
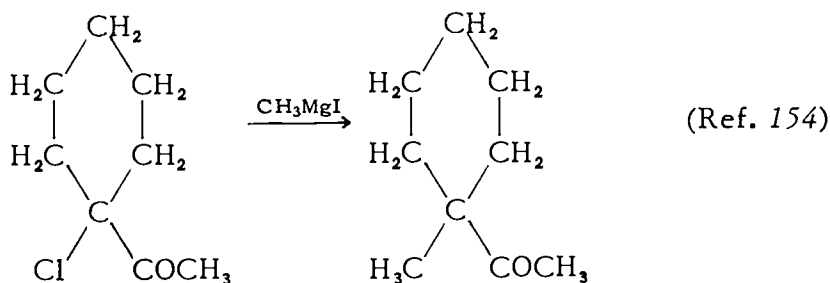
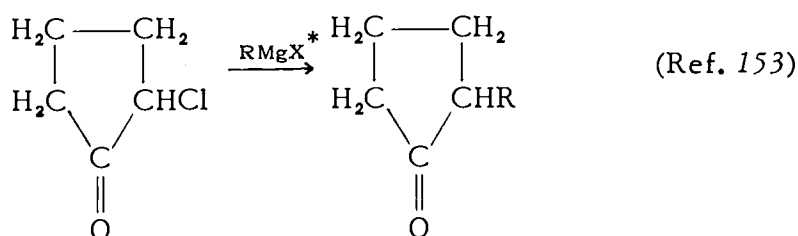
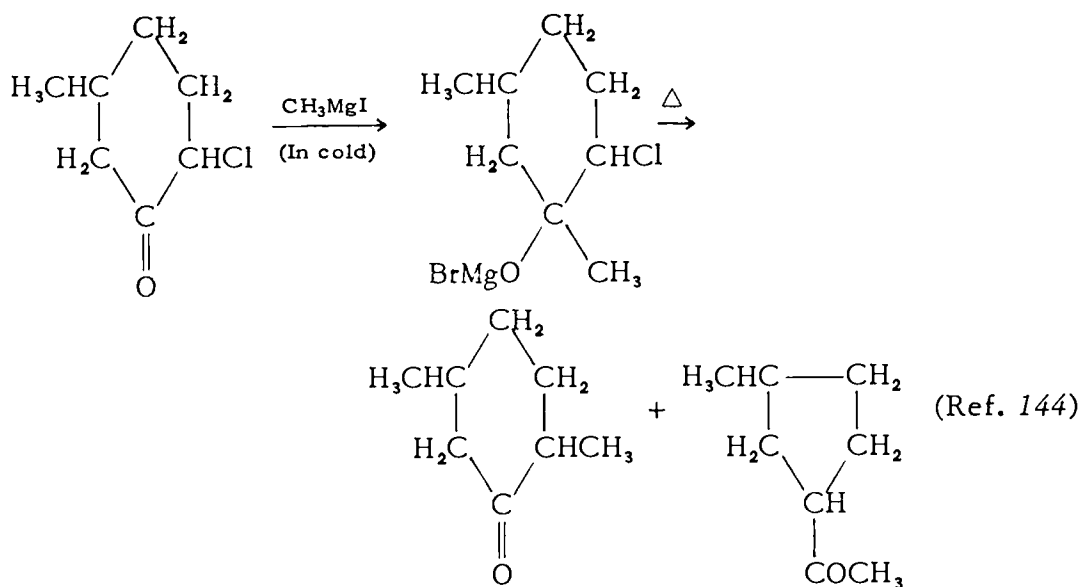
¹⁵⁴Sackur, *Compt. rend.*, 208, 1092-4 (1939); *Chem. Abstr.*, 33, 9296 (1939); *Chem. Zentr.*, 1940, 1, 859.

¹⁵⁵Tchoubar and Sackur, *Compt. rend.*, 207, 1105-6 (1938); *Chem. Abstr.*, 33, 2111 (1939).

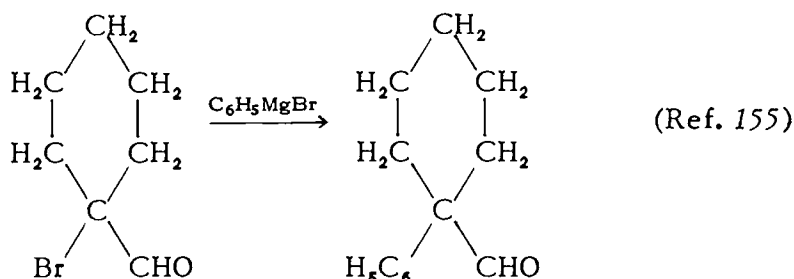
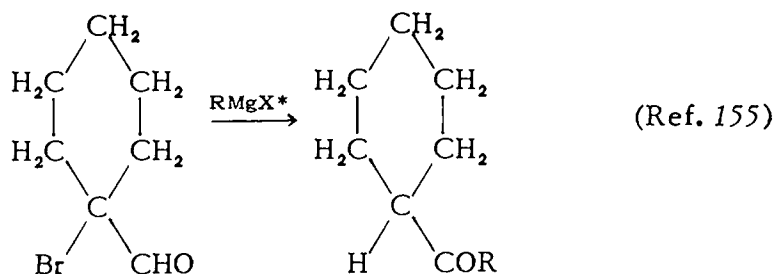
*R = CH₃, C₂H₅, *i*-C₃H₇



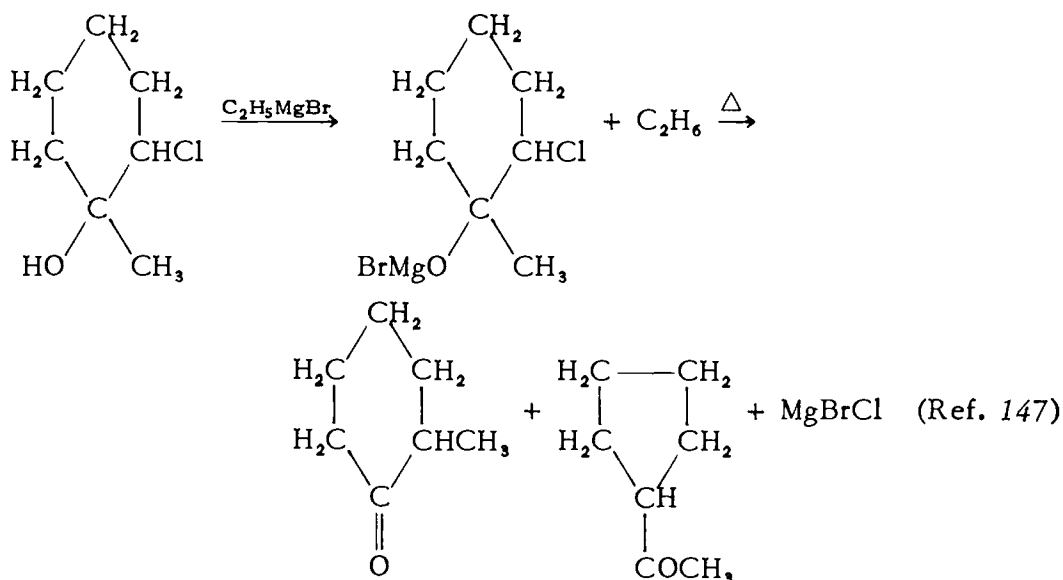
* R = 2-CH₃C₆H₄, 3-CH₃C₆H₄.



* R = CH₃, C₂H₅, *i*-C₃H₇, C₆H₅.



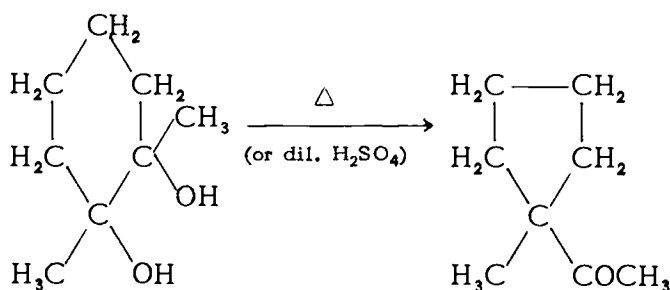
That these reactions are not simple metatheses is convincingly demonstrated by the work of Tiffeneau,¹⁴⁷ who was able to isolate several halohydrins and to demonstrate that the corresponding halomagnesium halohydrinates, upon heating, undergo decomposition and rearrangement to yield the α -substituted ketones and magnesium halide.



That, in the case of the cyclohexanones, the rearrangement takes, in part, a course leading to the contraction of the cyclohexane to a cyclopentane ring is altogether characteristic of cyclohexane systems. This rearrangement in particular bears a close resemblance to the 1,2-dimethylcyclohexane-1,2-diol rearrangement observed by Nametkin and Delektorsky.¹⁵⁶

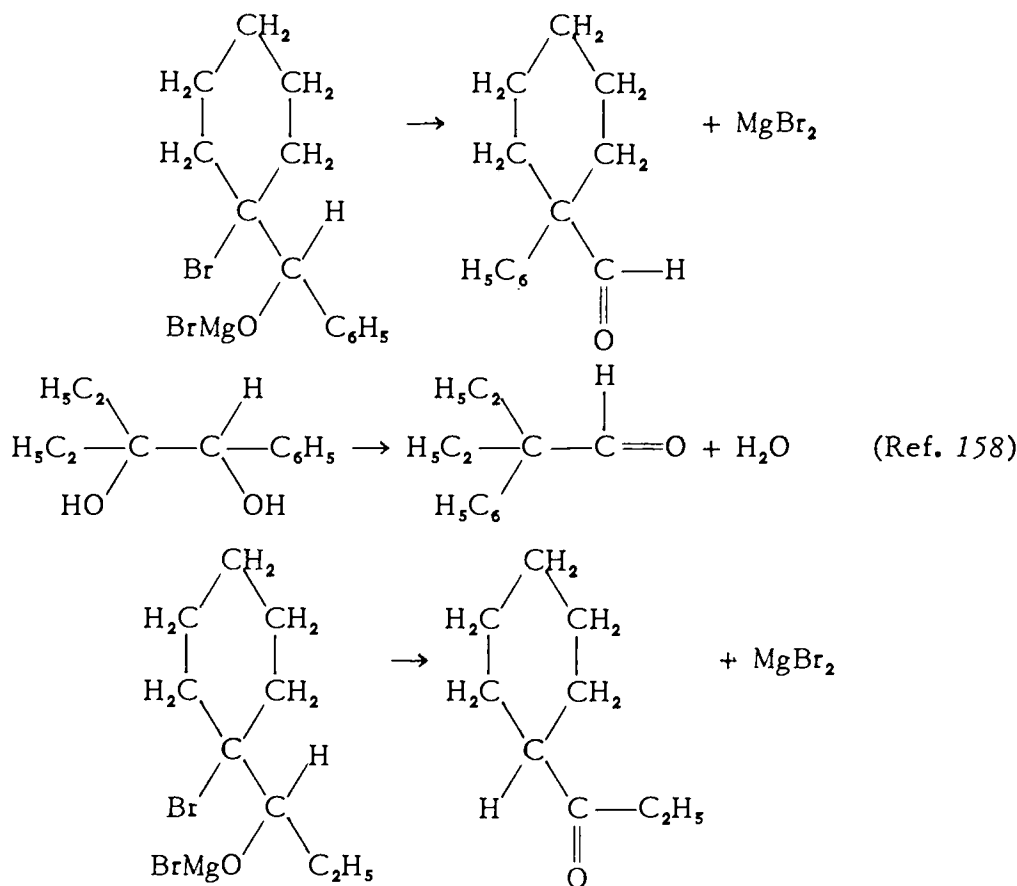
* R = CH₃, C₂H₅.

¹⁵⁶Nametkin and Delektorsky, *Ber.*, 57B, 583-7 (1924).



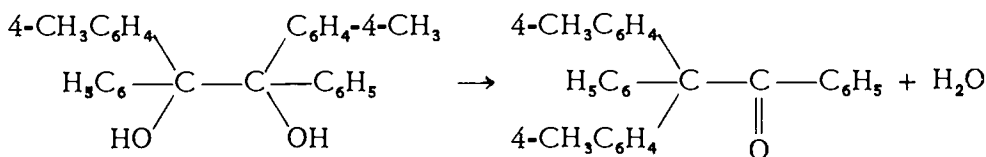
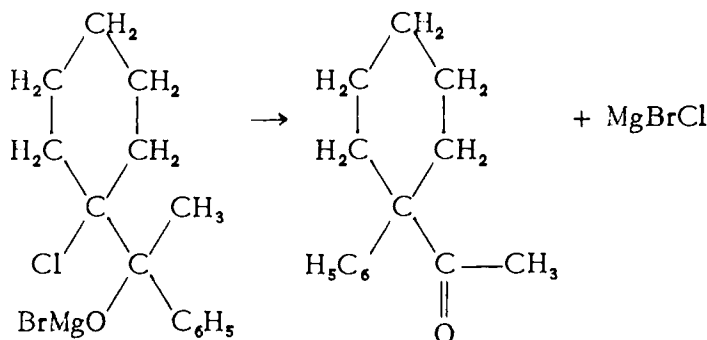
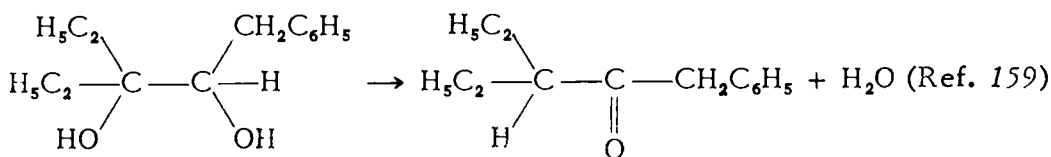
Of especial interest is Sackur's¹⁵⁴ demonstration that 1-chloro-1-acetylcyclohexane, when treated with phenylmagnesium bromide, and 1-chloro-1-benzoylcyclohexane, when treated with methylmagnesium iodide, both yield 1-acetyl-1-phenylcyclohexanone—an illustration of the relative migration tendencies of aryl and alkyl groups in rearrangements of this kind, and, incidentally, a phenomenon that could not conceivably result from simple metathesis.

All these rearrangements are strikingly similar to those of the well-known pinacol-pinacolone type.¹⁵⁷



¹⁵⁷See, e.g.: Porter, "Molecular Rearrangements," The Chemical Catalog Co., Inc., New York, 1928, Chapter III; Wallis, Chapter 12, Vol. I of "Organic Chemistry," edited by Gilman, John Wiley and Sons, New York, 2nd ed., 1943.

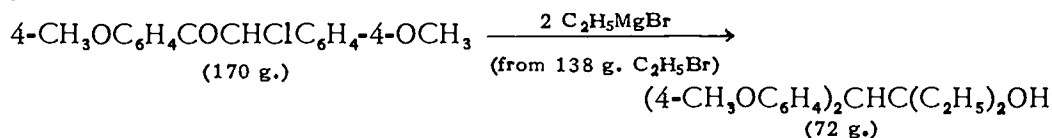
¹⁵⁸Tiffeneau and Lévy, *Bull. soc. chim.*, [4], 33, 735-79 (1923).



(Ref. 160)

Newman and Booth¹⁶¹ have reported that treatment of 2-chloro-4-methylcyclohexanone with phenylmagnesium bromide leads to a mixture of 2-phenyl-4-methylcyclohexanone and 2-phenyl-5-methylcyclohexanone, with the former apparently predominating. However, since this reaction involved prolonged refluxing in xylene solution, opportunities for rearrangement suggest caution in drawing conclusions from it.

A reaction in which halogen replacement with rearrangement takes place, together with addition at the carbonyl double bond, has been reported by Foldi and Demjén.¹⁶²



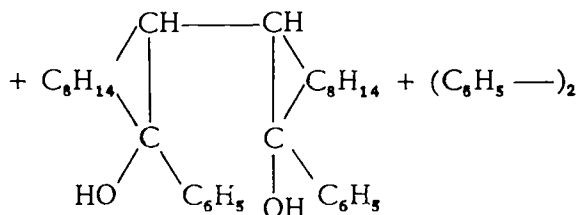
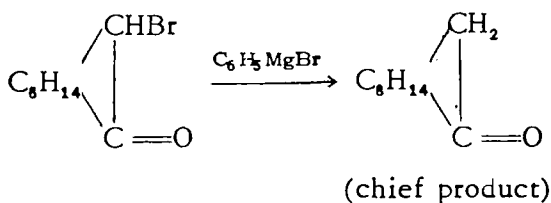
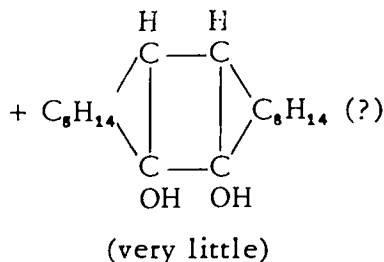
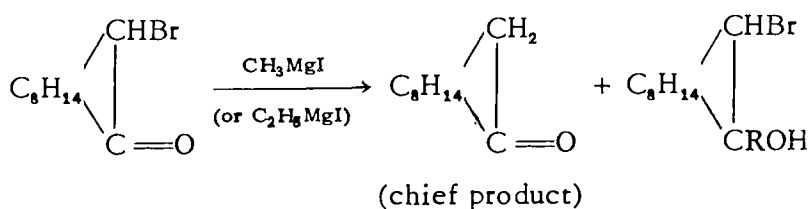
An interesting variation occurs in the behavior of the α -bromo aldehyde studied by Tchoubar and Sackur (*loc. cit.*¹⁵⁵). In this case, the intermediate halomagnesium bromohydrates are evidently relatively unstable, for it proved impossible to isolate the bromohydrins even when operations were conducted at 0° . When alkyl (methyl, ethyl) Grignard reagents were employed, migration of a hydrogen atom occurred, resulting in formation

¹⁵⁹Lévy, *Bull. soc. chim.*, [4], 33, 1655-66 (1923).

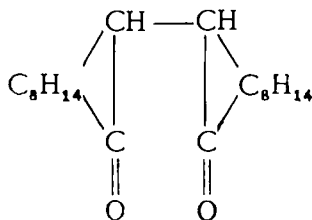
¹⁶⁰Bachmann and Moser, *J. Am. Chem. Soc.*, 54, 1124-33 (1932).

¹⁶¹Newman and Booth, *J. Org. Chem.*, 12, 737-9 (1947).

¹⁶²Foldi and Demjén, *Ber.*, 74B, 930-4 (1941).



In the light of present knowledge, the constitution assigned by Malmgren to the minor product of the alkyl Grignard reagent reactions appears highly improbable. There can be little doubt that the substance isolated by Malmgren was, in reality, the coupling product (see Grignard Reagent Coupling, Chapter XIV).



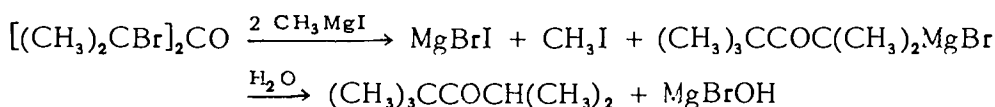
The biphenyl detected among the products of the phenylmagnesium bromide reaction doubtless arises in part from the Wurtz side-reaction in the preparation of the Grignard reagent and in part from the coupling reaction.

Kohler and Johnstin¹⁶⁷ treated 1-bromo-1-benzoyl-2,2-diphenylethane with a large excess of phenylmagnesium bromide and obtained an enolate which, upon treatment with water, yielded the unbrominated ketone. Benzoylation of the enolate yielded a product which, because of its ease

¹⁶⁷Kohler and Johnstin, *Am. Chem. J.*, 33, 35-45 (1905).

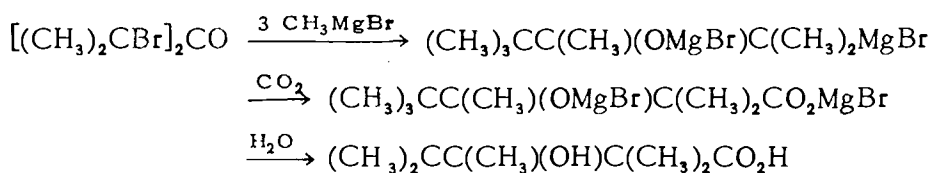
of hydrolysis, they formulated as a benzoic ester. At that time, Kohler also believed that the products of the Grignard reaction (in addition to the enolate) are biphenyl and magnesium bromide.

Umnowa¹⁶⁸ found that when α, α' -dibromoisobutyron reacts with two molecules of methylmagnesium iodide or bromide, one bromine atom is replaced by a methyl group while the other is displaced in such a way that upon hydrolysis of the product, it is replaced by a hydrogen atom. She described the reaction as follows:

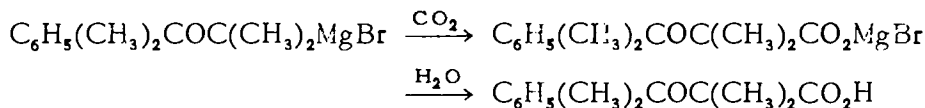


The reaction with phenylmagnesium bromide is similar.¹⁶⁹

By prolonged (sixty hours) heating with an excess of methyl Grignard reagent, she believed that she was able to bring about the reaction of a third molecule of the Grignard reagent.

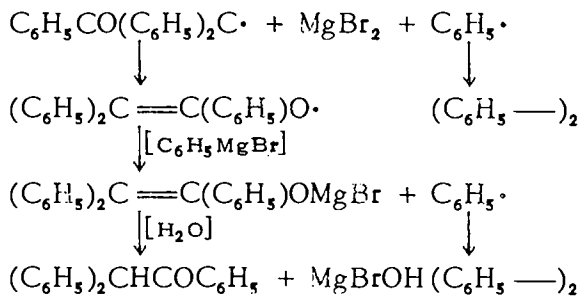
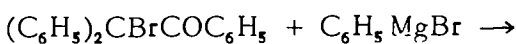


Carbonation of the initial product also yields a carboxylic acid.



For these reasons, she formulated the product of reaction of two molecules of Grignard reagent with one molecule of the dibromo ketone as a Grignard reagent rather than as an enolate.

Löwenbein and Schuster¹⁷⁰ recognized the product of the interaction of phenylmagnesium bromide with α -bromo- α, α -diphenylacetophenone as an enolate, but they represented the reaction as consuming two equivalents of the Grignard reagent, and believed that biphenyl is one of its products.

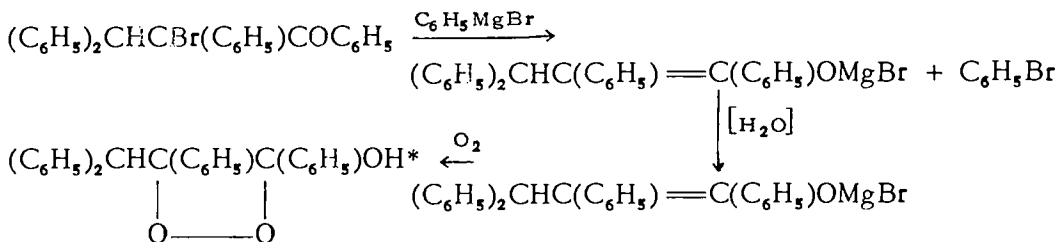


¹⁶⁸Umnowa, *J. Russ. Phys.-Chem. Soc.*, 44, 1395-1406 (1912); *Chem. Zentr.*, 1913, 1, 1402; *Chem. Abstr.*, 7, 987 (1913).

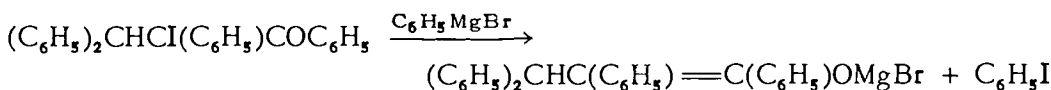
¹⁶⁹Umnowa, *J. Russ. Phys.-Chem. Soc.*, 45, 881-4 (1913); *Chem. Abstr.*, 7, 3601 (1913).

¹⁷⁰Löwenbein and Schuster, *Ann.*, 481, 106-19 (1930).

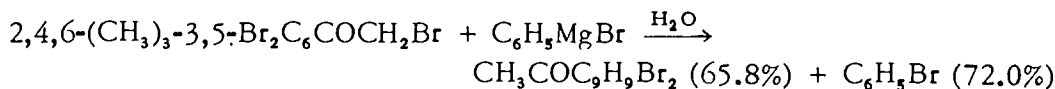
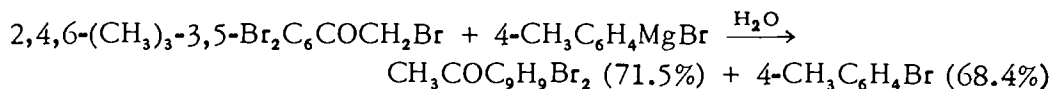
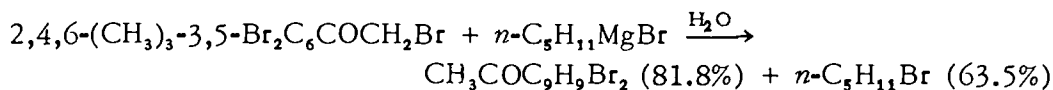
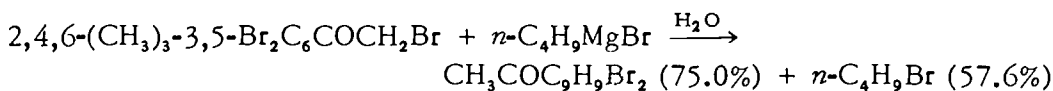
Kohler and Tishler¹⁷¹ studied the reaction of phenylmagnesium bromide with α -bromo- α,β,β -triphenylpropiophenone with special attention to the structure of the reaction product. Upon hydrolysis of the Grignard complex, they obtained a relatively stable enol which was converted by means of atmospheric oxygen to a known "enol peroxide."¹⁷²



The fate of the hydrocarbon residue of the Grignard reagent was established beyond question by employing the corresponding α -iodo ketone. The iodobenzene formed was isolated and identified as the iodochloride. Kohler and Tishler could detect only the amount of biphenyl usually arising from the Wurtz side-reaction in the preparation of a phenylmagnesium halide.



Further confirmation of the course of such reactions has been supplied by Fuson *et al.*¹⁷³ and by Howk and McElvain.¹⁷⁴



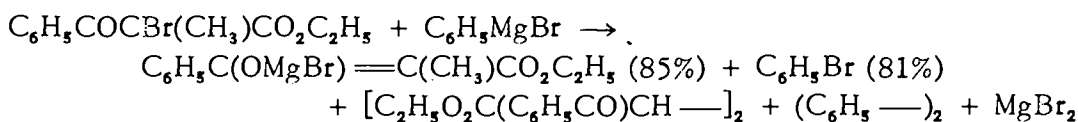
¹⁷¹Kohler and Tishler, *J. Am. Chem. Soc.*, 54, 1594-600 (1932).

¹⁷²Kohler, *Am. Chem. J.*, 36, 177-95 (1906).

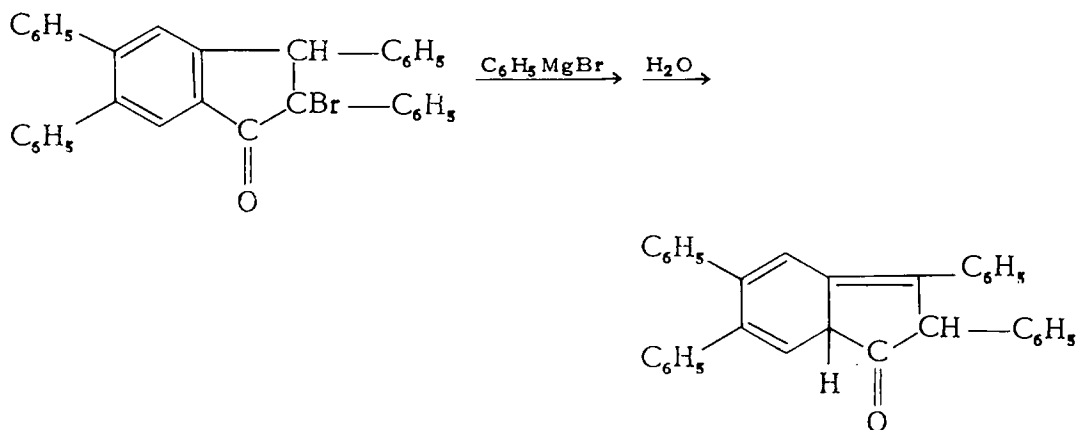
*Kohler's formulation of his "enol peroxides" is undoubtedly erroneous. Rigaudy, *Compt. rend.*, 226, 1993-5 (1948), has pointed out the probable instability of a 2-carbon 2-oxygen four-membered ring, has cited the similarity in properties between Kohler's "enol peroxides" and known hydroperoxides, and has shown that the ultraviolet absorption spectrum of one of Kohler's "enol peroxides" bears evidence of the presence of a carbonyl group and is closely similar to those of analogous ketones but quite different from that of an analogous carbinol. The more probable formulation in this instance would seem to be $(\text{C}_6\text{H}_5)_2\text{CHC}(\text{OOH})(\text{C}_6\text{H}_5)\text{COC}_6\text{H}_5$.

¹⁷³Fisher, Snyder, and Fuson, *J. Am. Chem. Soc.*, 54, 3665-74 (1932).

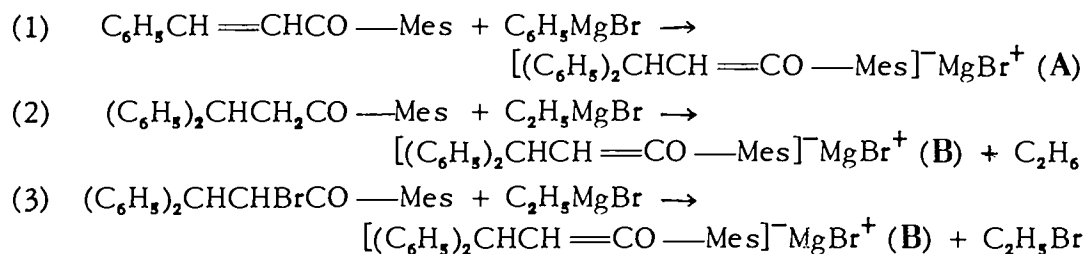
¹⁷⁴Howk and McElvain, *J. Am. Chem. Soc.*, 55, 3372-80 (1933).



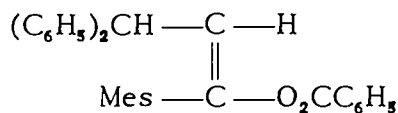
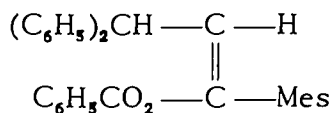
A similar dehalogenation reaction, in which there is, however, a simultaneous rearrangement of double bonds within the molecule, has been reported by Allen and Gates.¹⁷⁵



Probable mechanism of α -halo ketone dehalogenation. Whereas the halomagnesium compounds arising from the dehalogenation of α -halo ketones by Grignard reagents are, in general, identical in chemical properties with the enolates derived by treatment of the corresponding non-halogenated ketones with Grignard reagents, it seems altogether logical to formulate them as enolates. A rather interesting study by Kohler *et al.*¹⁷⁶ may be cited in illustration.*



In appearance, in solubility, and in many chemical properties the products of reaction 1 (A) and of reactions 2 and 3 (B) appear to be identical. However, treatment of A with benzoyl chloride produces (in at least 96 percent yield) a benzoate melting at 161° , whereas similar treatment of B produces a benzoate melting at 148° . The two benzoates are evidently stereoisomers.



¹⁷⁵ Allen and Gates, *J. Am. Chem. Soc.*, 64, 2127-30 (1942).

¹⁷⁶ Kohler, Tishler, and Potter, *J. Am. Chem. Soc.*, 57, 2517-21 (1935).

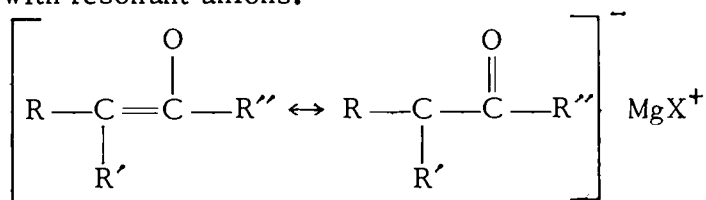
*Mes = mesityl = 2,4,6-(CH₃)₃C₆H₄-

Similar stereoisomers have been observed by Michael and Ross¹⁷⁷ in the products arising from the treatment of sodium enolates with chlorocarbonic ester.

The argument that halomagnesium compounds of the type under consideration should be formulated either as true Grignard reagents or as enolates depending upon the nature of the products formed in reactions with various reactants is now generally regarded as invalid. It is now well-known that many sodium enolates undergo C-carbonation, C-arylation, and C-alkylation,¹⁷⁸ and alkali-induced condensations are generally recognized as enolate additions at carbonyl double bonds.

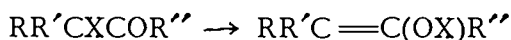
There is therefore nothing incongruous in the idea that some halomagnesium enolates may undergo C-carbonation, whereas others do not; that some may undergo C-acylation and C-alkylation, whereas others undergo O-acylation and O-alkylation, and still others may yield mixtures of C- and O-acylation or -alkylation products;¹⁷⁹ or that some may undergo addition reactions at carbonyl double bonds whereas others show little or no tendency to do so.

Such halomagnesium enolates are probably best formulated as ionic compounds with resonant anions.

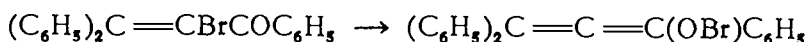


The products formed upon treatment of the enolates with various reagents are probably influenced, to some extent at least, by the relative contributions of the respective electronic forms to the character of the resonant ion, but may, in some cases, be determined primarily by steric factors.

Howk and McElvain (*loc. cit.*¹⁷⁴) have suggested that the Grignard reagent dehalogenation of α -halo ketones, with halomagnesium enolate formation, is preceded by rearrangement of the α -halo ketone to form an enol hypohalite.



As Kohler and Tishler (*loc. cit.*¹⁷¹) have pointed out, "even if one were disposed to believe in the possibility of such a shift of the halogen atom, it would seem incredible in compounds like α -bromo- β -phenylbenzalacetophenone where it would involve rearrangement of a conjugated to an allenic system."

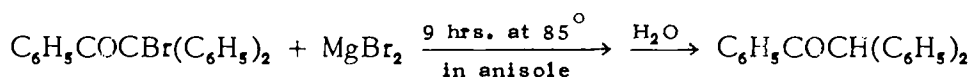
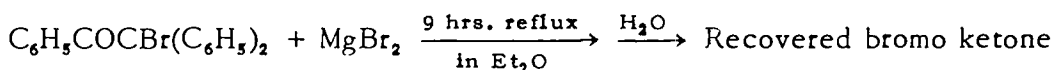
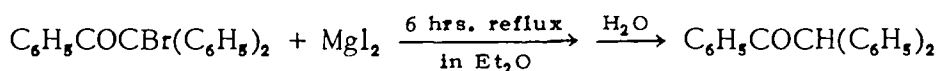


¹⁷⁷Michael and Ross, *J. Am. Chem. Soc.*, 53, 2394-414 (1931).

¹⁷⁸See, e.g., Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931).

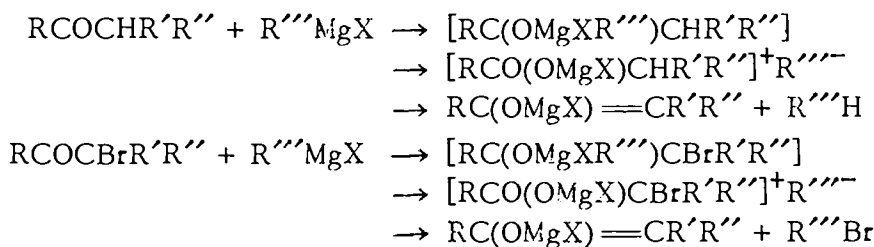
¹⁷⁹See, e.g., Kohler and Peterson, *J. Am. Chem. Soc.*, 55, 1073-82 (1933); Kohler and Potter, *ibid.*, 58, 2166-70 (1936).

Schönberg and Moubasher¹⁸⁰ attribute the conversion of α -bromo ketones to the corresponding unbrominated ketones, by heating with Grignard reagents and hydrolizing the resultant product, to the magnesium halide present rather than to the Grignard reagent itself. They were able to show that, in some cases at least, the conversion may be effected by magnesium iodide or magnesium bromide.

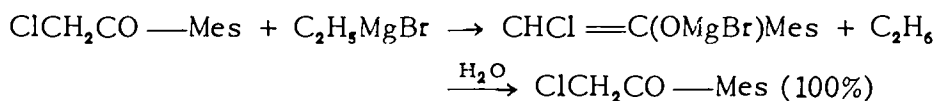
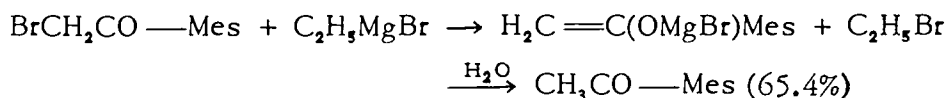


However, their work demonstrates only that the conversion may be effected in some cases by the halides. There is no evidence that it is not effected as readily, or even more readily, by Grignard reagents.

On the whole, there would seem to be no serious objection to postulating for enolate formation of this kind a mechanism very similar to that for enolate formation from the corresponding unhalogenated ketones.



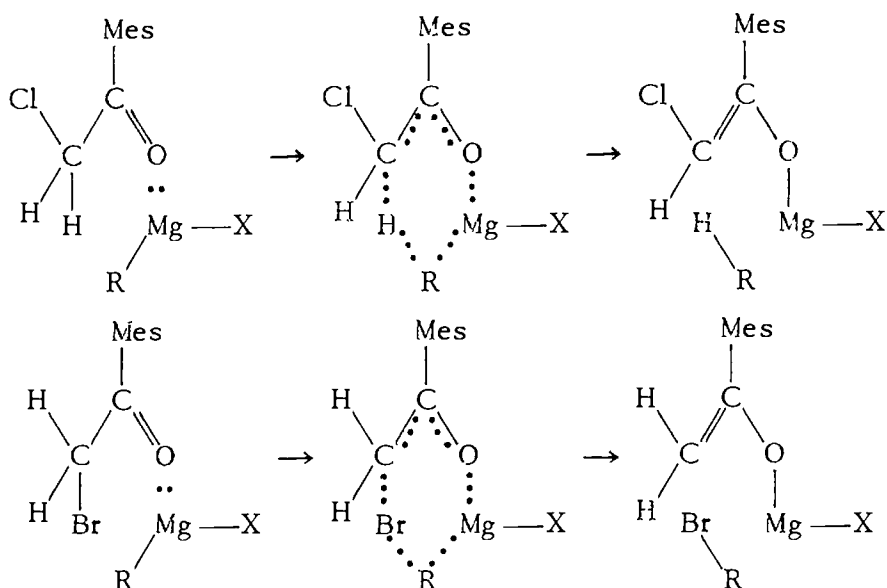
Such a postulate implies that the *alpha* halogen atom displays some disposition to react as "positive" halogen, although the actual presence of free positive halogen ions need not be assumed. On this basis the different behaviors of bromoacetomesitylene and chloroacetomesitylene¹⁸¹ are readily understandable, for bromine would certainly assume the rôle of "positive" halogen more readily than would chlorine.



As in the case of the ordinary ketone enolizations already discussed, these reactions may, of course, be formulated as concerted displacements involving quasi six-membered ring transition states.

¹⁸⁰Schönberg and Moubasher, *J. Chem. Soc.*, 1944, 462-3.

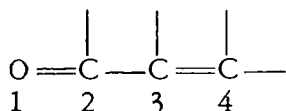
¹⁸¹Fisher, Snyder, and Fuson, *J. Am. Chem. Soc.*, 54, 3665-74 (1932).



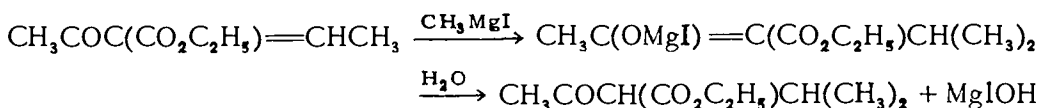
This is essentially the scheme proposed by Lutz *et al.*¹⁸² for "reductive enolization."

GRIGNARD REAGENT ADDITION TO CONJUGATED CARBONYL SYSTEMS

In terms of the conventional system of numbering for α,β -unsaturated aldehydes and ketones,



most aldehydes and many ketones react additively with Grignard reagents to give, predominantly or exclusively, the "normal" 1,2-addition product. Many ketones, however, give, predominantly or exclusively, the 1,4-addition product. Grignard¹⁸³ himself reported the 1,4-addition of methylmagnesium iodide to α -ethylideneacetoacetic ester.



Since then many examples of 1,4-addition of Grignard reagents to conjugated carbonyl systems have been reported, and various investigators, notably Kohler and his students, have studied the factors influencing the order of addition in reactions of this kind.

Despite the seeming wealth of data collected in Table VI-XVI the amount of detailed and thoroughly reliable information available is en-

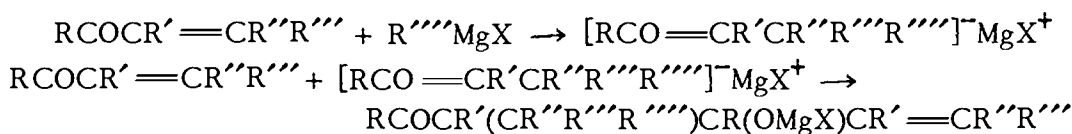
¹⁸²Lutz and Kibler, *J. Am. Chem. Soc.*, 62, 360-72 (1940); Lutz and Reveley, *ibid.*, 63, 3180-9 (1941).

¹⁸³Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).

tirely too meagre to justify the formulation of any broad generalizations concerning the factors affecting the order of addition of Grignard reagents to conjugated carbonyl systems. In far too many instances only the "expected" product, the major product, or the most readily isolated product has been reported, and that not always quantitatively. In such cases it is only when the yield is relatively high (above 50 percent) that the data may be regarded as having diagnostic significance. Even in supposedly quantitative studies, methods of product separation employed have not always been adequate, as has been pointed out by Alexander and Coraor.¹⁸⁴

Byproducts in general have been almost universally ignored, and little or no attention has been paid to the nature of theoretically significant condensation products. Condensation products probably arise from two principal sources: (a) ketol (or aldol) condensations, and (b) diene polymerizations.

The initial product of the 1,4-addition of a Grignard reagent to an α,β -unsaturated ketone is, of course, an enolate, and, when the enolate and the original ketone are of such nature that 1,2-addition of the enolate at the carbonyl double bond of the ketone may take place, ketolization occurs.



It is altogether conceivable that in cases of ketones with relatively reactive carbonyl double bonds practically all the initial 1,4-addition product formed may be consumed in subsequent ketol condensations, and the only product reported may be that of the competing, though not necessarily predominant, 1,2-addition reaction.

When the unsaturated ketone has one or more "active" hydrogen atoms attached to the non-olefinic carbon atom adjacent to the carbonyl group, enolization in the ordinary sense is also possible and may give rise to ketolization.

The products of "normal" 1,2-addition at the carbonyl double bond often undergo further unsaturation, either during the Grignard reaction or in the processes of hydrolysis and recovery, forming conjugated dienes which polymerize more or less readily.

Furthermore, alkyl or aralkyl Grignard reagents may effect reduction of unsaturated aldehydes and ketones as they do with the corresponding saturated compounds (see Grignard Reductions of Aldehydes and Ketones, p. 147). The only material isolated by Lutz and Reveley¹⁸⁵ as a result

¹⁸⁴Alexander and Coraor, *J. Am. Chem. Soc.*, 73, 2721-3 (1951).

¹⁸⁵Lutz and Reveley, *J. Am. Chem. Soc.*, 63, 3178-80 (1941).

TABLE VI-XVI
ADDITION OF GRIGNARD REAGENTS TO CONJUGATED CARBONYL SYSTEMS OF THE TYPE $\text{RCOCR}^1=\text{CR}^2\text{R}^3$

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	$\frac{1,2\text{-}}{\text{Add}^n}$ (%)	$\frac{1,4\text{-}}{\text{Add}^n}$ (%)	$\frac{\text{Cond}^n}{(\%)}$	<u>Ref.[†]</u>
H	H	H	H	CH_3MgBr	52	...	...	VI-XVII: 20, 68, 72, 272, 361
H	H	H	H	CH_3MgBr	73	...	...	48
H	H	H	H	CH_3MgBr	80	...	...	258
H	H	H	H	CH_3MgI	52	...	...	334, 20, 66, 72, 198, 361
H	H	H	H	$(\equiv \text{CMgBr})_2$	29 [†]	...	ca. 54	394, 81, 420
H	H	H	H	$(\equiv \text{CMgBr})_2$	36 [§]	393, 391
H	H	H	H	$\text{C}_2\text{H}_5\text{MgBr}$	57 [¶]	70, 67, 72
H	H	H	H	$\text{C}_2\text{H}_5\text{MgBr}$	65	...	...	272, 33
H	H	H	H	$\text{C}_2\text{H}_5\text{MgBr}$	67	...	ca. 11	185
H	H	H	H	$\text{H}_2\text{C}=\text{CHCH}_2\text{MgBr}$	35-40	...	...	258
H	H	H	H	$n\text{-C}_3\text{H}_7\text{MgBr}$	41	...	...	68, 72

*In cases where the α,β -unsaturated carbonyl compound itself is incapable of enolization, condensation can take place only through the enolate formed by 1,4-addition.

[†]To avoid duplication and conserve space a separate listing of references for this table is omitted. For the aldehydes ($\text{R} = \text{H}$), the reference numbers are those of Table VI-XVII; for the ketones ($\text{R} \neq \text{H}$), those of Table VI-XVIII. In general, the yields recorded are those reported in the first reference listed; other references may be regarded as supplementary.

[‡]The addition product reported is $[\equiv \text{CCH}(\text{OH})\text{CH}=\text{CH}_2]_2$.

[§]The principal addition product reported is $\text{HC}\equiv\text{C}(\text{H}_2\text{C}=\text{CH})\text{CHOH}$.

[¶]It is reported that the maximum yield of addition product (57.4%) was obtained with a ratio of 1.85 mole of Grignard reagent to 1.00 mole of aldehyde; a smaller excess of Grignard reagent or an excess of aldehyde gave lower yields.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
H	H	H	H	<i>n</i> -C ₃ H ₇ MgBr	60	...	...	272,33, 249
H	H	H	H	<i>i</i> -C ₃ H ₇ MgBr	15	...	...	33
H	H	H	H	Butenyl-MgBr*	<25	...	...	258
H	H	H	H	<i>n</i> -C ₄ H ₉ MgBr	35	...	...	68,72
H	H	H	H	<i>n</i> -C ₄ H ₉ MgBr	45	...	...	272,33
H	H	H	H	<i>i</i> -C ₄ H ₉ MgBr	+	...	...	33
H	H	H	H	CH ₃ O(CH ₂) ₃ MgCl	46	...	...	409
H	H	H	H	<i>n</i> -C ₅ H ₁₁ MgBr	46	...	...	118
H	H	H	H	<i>i</i> -C ₅ H ₁₁ MgBr	59	...	...	72
H	H	H	H	C ₆ H ₅ MgBr	52	0	...	179,41, 185,238
H	H	H	H	C ₆ H ₅ MgBr	75	...	...	69
H	H	H	H	<i>n</i> -C ₆ H ₁₃ MgBr	94	...	...	72
H	H	H	H	C ₆ H ₅ CH ₂ MgX†	ca. 5	...	...	69; <i>c.f.</i> 61
H	H	H	H	2-CH ₃ C ₆ H ₄ MgBr	55	...	...	69
H	H	H	H	4-CH ₃ C ₆ H ₄ MgBr	57	...	...	69,41
H	H	H	H	(C ₂ H ₅ O) ₂ CHC≡CMgBr	+	...	...	423
H	H	H	H	C ₆ H ₅ (CH ₂) ₂ MgBr	>57	...	...	69
H	H	H	H	C ₆ H ₅ (CH ₂) ₃ MgBr	57	...	...	69
H	Br	H	H	CH ₃ MgI	+‡	...	...	199
H	Br	H	H	(≡CMgBr) ₂	+§	...	...	391

*Ou Kiun-Houo (VI-XVI: 258) reported this reaction as involving crotylmagnesium bromide; *c.f.*, however, Chapter XVII, Allylic Rearrangements in Grignard Reactions. The product reported is H₂C=CH[H₂C=CHCH(CH₃)]CHOH.

†X = Cl, Br.

‡The yield is reported as "good."

§The product reported is HC≡C(H₂C=CBr)CHOH.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
H	CH ₃	H	H	(≡CMgBr) ₂	52	...	...	65
H	H	CH ₃	H	CH ₃ MgCl	81-86	...	...	53
H	H	CH ₃	H	CH ₃ MgBr	30	...	...	240,146, 343
H	H	CH ₃	H	CH ₃ MgI	90	...	...	194,59, 121,281
H	H	CH ₃	H	(≡CMgBr) ₂	ca. 36*	...	...	397,81, 420
H	H	CH ₃	H	(≡CMgBr) ₂	29†	...	...	393,395
H	H	CH ₃	H	C ₂ H ₅ MgBr	65	...	...	280,146, 281,343
H	H	CH ₃	H	C ₂ H ₅ MgBr	70.3	0.1	11.4	309,272
H	H	CH ₃	H	C ₂ H ₅ MgBr	90	...	...	194
H	H	CH ₃	H	H ₂ C=CHCH ₂ MgBr	+	trace	...	309
H	H	CH ₃	H	H ₂ C=CHCH ₂ MgBr	ca. 80	...	...	136,82, 181,258, 264
H	H	CH ₃	H	<i>n</i> -C ₃ H ₇ MgCl	74	...	...	6
H	H	CH ₃	H	<i>n</i> -C ₃ H ₇ MgBr	46	...	...	240,146, 280,281, 343
H	H	CH ₃	H	<i>n</i> -C ₃ H ₇ MgBr	78.3	trace	7.6	309
H	H	CH ₃	H	<i>i</i> -C ₃ H ₇ MgBr	ca. 30	...	...	281,343, 350
H	H	CH ₃	H	<i>i</i> -C ₃ H ₇ MgBr	46.5	0.3	34.1	309

*The addition product reported is $[\equiv\text{CCH}(\text{OH})\text{CH}=\text{CHCH}_3]_2$.

†The addition product reported is $\text{HC}\equiv\text{C}(\text{CH}_3\text{CH}=\text{CH})\text{CHOH}$.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
H	H	CH ₃	H	H ₂ C=CHC≡CMgBr	36.3	...	...	406
H	H	CH ₃	H	<i>n</i> -C ₄ H ₉ MgBr	51	...	...	204
H	H	CH ₃	H	<i>i</i> -C ₄ H ₉ MgBr	14.8- 18.6*	...	21-28	138
H	H	CH ₃	H	<i>i</i> -C ₄ H ₉ MgBr	<i>ca.</i> 30	...	...	281,343
H	H	CH ₃	H	<i>i</i> -C ₄ H ₉ MgI	2†	...	60	138
H	H	CH ₃	H	<i>s</i> -C ₄ H ₉ MgBr	42.2‡	...	...	138
H	H	CH ₃	H	<i>s</i> -C ₄ H ₉ MgBr	15.3§	...	+	138
H	H	CH ₃	H	<i>t</i> -C ₄ H ₉ MgCl	3.4	...	...	240
H	H	CH ₃	H	<i>t</i> -C ₄ H ₉ MgCl	30.6	20.3	39.3	308,309
H	H	CH ₃	H	<i>t</i> -C ₄ H ₉ MgBr	3.0	10.8	55.4	309
H	H	CH ₃	H	H ₂ C=C(CH ₃)C≡CMgBr	43.2	...	...	406
H	H	CH ₃	H	<i>i</i> -C ₅ H ₁₁ MgBr	45	...	...	121,343
H	H	CH ₃	H	<i>t</i> -C ₅ H ₁₁ MgCl	16.3	22.6	45.7	309
H	H	CH ₃	H	C ₆ H ₅ MgBr	70	...	...	40,61
H	H	CH ₃	H	C ₆ H ₅ MgBr	<i>ca.</i> 90	0.1	7.1	309
H	H	CH ₃	H	CH ₃ CH=C(CH ₃)C≡CMgBr	80.0	...	...	407
H	H	CH ₃	H	<i>n</i> -C ₄ H ₉ C≡CMgBr	+	...	...	127
H	H	CH ₃	H	(CH ₂) ₅ CHC≡CMgBr	52	...	...	126
H	H	CH ₃	H	1-C ₁₀ H ₇ MgBr	+	...	...	301
H	H	CH ₃	H	CH ₃ CH=CHCH(OMgBr)C≡CMgBr	40	...	...	398
H	H	H ₂ C=CH	H	CH ₃ MgBr	75	...	...	364
H	H	H ₂ C=CH	H	H ₂ C=CHCH ₂ MgBr	90	...	...	365

*Yields of reduction product (CH₃CH=CHCH₂OH) from a trace to 20% are also reported.

†A 10% yield of crude reduction product (CH₃CH=CHCH₂OH) is also reported.

‡Reaction at 0°.

§Twenty-four hours at room temperature.

TABLE VI-XVI (Continued)

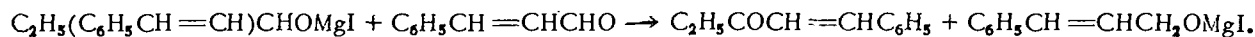
<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
H	H	<i>n</i> -C ₃ H ₇	H	<i>n</i> -C ₃ H ₇ MgBr	75	...	...	72
H	H	CH ₃ (CH=CH) ₂	H	(≡CMgBr) ₂ [*]	20.4	...	...	400
H	H	CH ₃ (CH=CH) ₂	H	RC≡CMgBr †	26.8	...	...	126
H	H	C ₆ H ₅	H	CH ₃ MgBr	+	...	...	178,243
H	H	C ₆ H ₅	H	CH ₃ MgI	62	...	...	380,40, 61,295; cf. 219
H	H	C ₆ H ₅	H	(≡CMgBr) ₂	+‡	...	...	149,81
H	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	67	...	...	173,138, 229
H	H	C ₆ H ₅	H	C ₂ H ₅ MgI	+§	...	...	219
H	H	C ₆ H ₅	H	<i>n</i> -C ₄ H ₉ MgBr	36.5¶	...	...	267
H	H	C ₆ H ₅	H	<i>i</i> -C ₄ H ₉ MgBr	+‡	...	...	229,138
H	H	C ₆ H ₅	H	<i>t</i> -C ₅ H ₁₁ MgCl	...	10	...	358
H	H	C ₆ H ₅	H	4-BrC ₆ H ₄ MgBr	+	...	...	360
H	H	C ₆ H ₅	H	4-ClC ₆ H ₄ MgI	ca. 88	...	...	41
H	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	51	...	...	252,200
H	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	63	...	...	44,184
H	H	C ₆ H ₅	H	4-CH ₃ C ₆ H ₄ MgBr	39	...	...	41

*The addition product reported is [≡CCH(OH)(CH=CH)₂CH₃]₂.

†R = 1-cyclohexenyl.

‡The addition product reported is [≡CCH(OH)CH=CHC₆H₅]₂.

§The products isolated obviously result from a Meerwein oxidation-reduction;



¶A ca. 15% yield of reduction product (C₆H₅CH=CHCH₂OH) is also reported.

‡The product is reported as obtained "in satisfactory yield and purity."

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
H	H	C ₆ H ₅	H	4-CH ₃ OC ₆ H ₄ MgBr	16	0	...	360
H	H	C ₆ H ₅	H	(C ₂ H ₅) ₂ N(CH ₂) ₃ MgCl	+	...	...	233
H	H	C ₆ H ₅	H	C ₆ H ₅ CH(CO ₂ Na)MgCl*	75	...	...	158
H	H	RCH=CHC- (CH ₃)=CH†	H	C ₂ H ₅ OC≡CMgBr	+	...	...	384
H	Br	C ₆ H ₅	H	CH ₃ MgI	+	...	...	295
H	Br	C ₆ H ₅	H	C ₆ H ₅ MgBr	+	...	...	184
H	CH ₃	CH ₃	H	CH ₃ MgI	+	...	...	350
H	CH ₃	CH ₃	H	RMgBr†	+	...	...	1
H	CH ₃	C ₂ H ₅	H	CH ₃ MgI	65	...	...	121
H	CH ₃	C ₂ H ₅	H	C ₂ H ₅ MgBr	88	...	...	30,343
H	CH ₃	C ₂ H ₅	H	<i>n</i> -C ₃ H ₇ MgCl	83	...	...	30,343
H	CH ₃	C ₂ H ₅	H	<i>i</i> -C ₄ H ₉ MgBr	67.5	...	...	30
H	CH ₃	C ₂ H ₅	H	<i>i</i> -C ₅ H ₁₁ MgBr	80	...	...	30
H	CH ₃	C ₆ H ₅	H	CH ₃ MgI	+	...	...	425
H	CH ₃	RCH ₂ †§	H	(≡CMgBr) ₂	ca. 40¶	...	...	147
H	CH ₃	RCH ₂ †§	H	BrMgOCH ₂ CH=CHC≡CMgBr	+	...	...	404
H	CH ₃	RCH ₂ †§	H	BrMgOCH ₂ CH(CH ₃)C≡CMgBr	81	...	...	402,141
H	CH ₃	RCH ₂ †§	H	<i>n</i> -C ₄ H ₉ C≡CMgBr	92	...	...	403
H	CH ₃	RCH ₂ †§	H	CH ₃ OCH ₂ CH=C(CH ₃)C≡CMgBr	+	...	...	157

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

†R = 2,6,6-trimethyl-1-cyclohexenyl.

‡R = CH₃, C₂H₅, *i*-C₅H₁₁.

§This is the so-called "β-ionone C₁₄ aldehyde" (VI-XVII: 402, 403).

¶The addition product reported is [≡CCH(OH)C(CH₃)=CHCH₂R]₂.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R³</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
H	CH ₃	RCH ₂ *†	H	CH ₃ OCH(CH ₃)CH=CHC≡CMgBr	94	...	...	403
H	CH ₃	RCH ₂ *†	H	<i>n</i> -C ₄ H ₉ OCH ₂ CH=C(CH ₃)- C≡CMgBr	<i>ca.</i> 80	...	...	157
H	CH ₃	RCH ₂ *†	H	C ₆ H ₅ OCH ₂ CH=C(CH ₃)- C≡CMgBr	<i>ca.</i> 28	...	...	157
H	H	CH ₃	CH ₃	C ₁₀ H ₁₉ MgBr‡	+	...	...	239
H	H	CH ₃	(CH ₃) ₂ C=CH(CH ₂) ₂	RMgX§	+	...	...	9
H	H	CH ₃	(CH ₃) ₂ C=CH(CH ₂) ₂	CH ₃ CH=C(CH ₃)C≡CMgBr	72.9	...	...	407
H	H	CH ₃	(CH ₃) ₂ C=CH(CH ₂) ₂	(C ₂ H ₅) ₂ N(CH ₂) ₃ MgCl	+	...	...	233
H	Br	Br	CO ₂ H	CH ₃ MgI	≤ 50¶	...	...	302
H	Br	Br	CO ₂ H	C ₂ H ₅ MgBr	≤ 50¶	...	...	302
H	Cl	Cl	CO ₂ H	CH ₃ MgI	+¶	...	...	302
H	Cl	Cl	CO ₂ H	C ₂ H ₅ MgBr	+¶	...	...	302
CH ₃	H	H	H	<i>n</i> -C ₄ H ₉ C≡CMgBr	51	...	...	VI-XVIII: 83
CH ₃	H	H	H	R'C≡CMgBr‡	45-50	...	...	84
C ₆ H ₅	H	H	H	CH ₃ MgI	0	+	...	256
C ₆ H ₅	H	H	H	Butenyl-MgBr	...	...	+	255
C ₆ H ₅	H	H	H	C ₆ H ₅ MgBr	0	+	...	256
CH ₃	H	Cl	H	CH ₃ MgBr	48	...	...	629
CH ₃	H	Cl	H	H ₂ C=CHCH ₂ MgBr	85	...	...	629

*R = 2,6,6-trimethyl-1-cyclohexenyl.

†This is the so-called "β-ionone C₁₄ aldehyde" (VI-XVII: 402, 403).

‡From 1-bromo-2-(4-methyl-3-cyclohexen-1-yl)propane.

§R = CH₃, C₂H₅, *i*-C₄H₉, C₆H₅.¶The product reported is a lactone, *i.e.*, a 3,4-dihalo-5-alkyldihydrofuran-2-one.

‡R' = 1-cyclohexenyl.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n (%)</u>	<u>1,4- Add'n (%)</u>	<u>Cond'n (%)</u>	<u>Ref.</u>
CH ₃	H	Cl	H	<i>n</i> -C ₄ H ₉ C≡CMgBr	95	...	...	629
CH ₃	H	CH ₃	H	CH ₃ MgBr	72.4	20.1	...	111
CH ₃	H	CH ₃	H	CH ₃ MgI	80.0	1.2	...	10,108, 109,110
CH ₃	H	CH ₃	H	C ₂ H ₅ MgBr	+	...	...	109,110
CH ₃	H	CH ₃	H	C ₂ H ₅ MgBr	41.4	38.6	...	112
CH ₃	H	CH ₃	H	C ₂ H ₅ MgBr	+	71.4	...	111
CH ₃	H	CH ₃	H	C ₂ H ₅ MgBr	≤ 47.6 x *	52.4 x *	...	622
CH ₃	H	CH ₃	H	<i>i</i> -C ₃ H ₇ MgBr	≤ 34.5 x *	65.5 x *	...	622
CH ₃	H	CH ₃	H	<i>i</i> -C ₄ H ₉ MgCl	+	...	...	109,110
CH ₃	H	CH ₃	H	<i>t</i> -C ₄ H ₉ MgCl	16.7	54.0	...	112
CH ₃	H	CH ₃	H	<i>t</i> -C ₄ H ₉ MgCl	≤ 38.3 x *	61.7 x *	...	622
CH ₃	H	CH ₃	H	<i>i</i> -C ₅ H ₁₁ MgBr	+	...	...	109,110
CH ₃	H	CH ₃	H	C ₆ H ₅ MgBr	+	37	...	111
CH ₃	H	CH ₃	H	<i>n</i> -C ₄ H ₉ C≡CMgBr	49.4	...	...	83
CH ₃	H	C ₂ H ₅	H	C ₂ H ₅ MgBr	≤ 56.9 x *	43.1 x *	...	622
CH ₃	H	C ₂ H ₅	H	<i>i</i> -C ₃ H ₇ MgBr	≤ 43.5 x *	56.5 x *	...	622
CH ₃	H	C ₂ H ₅	H	<i>t</i> -C ₄ H ₉ MgCl	≤ 52.0 x *	48.0 x *	...	622
CH ₃	H	CH ₃ CH=CH	H	RC≡CMgBr [†]	56	...	...	182,630
CH ₃	H	<i>n</i> -C ₃ H ₇	H	CH ₃ MgI	75	0	+	183,184
CH ₃	H	<i>n</i> -C ₃ H ₇	H	C ₂ H ₅ MgBr	65	...	...	183
CH ₃	H	<i>n</i> -C ₃ H ₇	H	C ₂ H ₅ MgBr	46.0	30.7	...	185
CH ₃	H	<i>n</i> -C ₃ H ₇	H	C ₂ H ₅ MgBr	+†	+†	...	186

*For the series of reactions studied, x is said to range from 0.86 to 1.00.

†R = 1-cyclohexenyl.

‡The ratio of 1,2-addition product to 1,4-addition product is reported to be about 3.1:1.0; the unsaturated ketone is the *trans* isomer.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n (%)</u>	<u>1,4- Add'n (%)</u>	<u>Ccnd'n (%)</u>	<u>Ref.</u>
CH ₃	H	<i>n</i> -C ₃ H ₇	H	C ₂ H ₅ MgBr	≤ 48.0 x*	52.0 x*	...	622
CH ₃	H	<i>n</i> -C ₃ H ₇	H	<i>n</i> -C ₃ H ₇ MgBr	55	...	...	183
CH ₃	H	<i>n</i> -C ₃ H ₇	H	<i>i</i> -C ₃ H ₇ MgBr	+†	+†	...	186
CH ₃	H	<i>n</i> -C ₃ H ₇	H	<i>i</i> -C ₃ H ₇ MgBr	≤ 37.0 x*	63.0 x*	...	622
CH ₃	H	<i>n</i> -C ₃ H ₇	H	<i>n</i> -C ₄ H ₉ MgBr	45	...	...	183
CH ₃	H	<i>n</i> -C ₃ H ₇	H	<i>i</i> -C ₄ H ₉ MgBr	38	...	...	183
CH ₃	H	<i>n</i> -C ₃ H ₇	H	<i>t</i> -C ₄ H ₉ MgCl	+†	+†	...	186
CH ₃	H	<i>n</i> -C ₃ H ₇	H	<i>t</i> -C ₄ H ₉ MgCl	≤ 40.1 x*	59.9 x*	...	622
CH ₃	H	<i>n</i> -C ₃ H ₇	H	<i>i</i> -C ₃ H ₁₁ MgBr	30	...	...	183
CH ₃	H	<i>n</i> -C ₃ H ₇	H	C ₆ H ₅ MgBr	20	...	...	183, 184
CH ₃	H	α -C ₄ H ₃ O§	H	C ₂ H ₅ MgBr	...	50	+	599
CH ₃	H	α -C ₄ H ₃ O§	H	<i>n</i> -C ₃ H ₇ MgBr	...	50	...	599
CH ₃	H	α -C ₄ H ₃ O§	H	<i>i</i> -C ₃ H ₇ MgBr	...	61	...	599
CH ₃	H	α -C ₄ H ₃ O§	H	<i>i</i> -C ₄ H ₉ MgBr	...	+	...	599
CH ₃	H	α -C ₄ H ₃ O§	H	<i>i</i> -C ₃ H ₁₁ MgI	...	44	...	224
CH ₃	H	α -C ₄ H ₃ O§	H	C ₆ H ₅ MgBr	...	...	+	140
CH ₃	H	C ₆ H ₅	H	CH ₃ MgI	+	...	...	206
CH ₃	H	C ₆ H ₅	H	C ₂ H ₅ MgI	37.2	56.5	6.3	111
CH ₃	H	C ₆ H ₅	H	C ₂ H ₅ MgI	+†	...	...	206

* For the series of reactions studied, *x* is said to range from 0.86 to 1.00.

† The ratio of 1,2-addition product to 1,4-addition product is reported to be about 1.2:1.0; the unsaturated ketone is the *trans* isomer.

‡ The ratio of 1,2-addition product to 1,4-addition product is reported to be about 1.9:1.0; the unsaturated ketone is the *trans* isomer.

§ The ketone is furfurylideneacetone; α -C₄H₃O = 2-furyl.

¶ The yield of diene (dehydration product) is reported as "good."

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
CH ₃	H	C ₆ H ₅	H	H ₂ C=CHCH ₂ MgBr	31	...	...	599
CH ₃	H	C ₆ H ₅	H	C ₂ H ₅ OC≡CMgBr	80	...	...	43
CH ₃	H	C ₆ H ₅	H	<i>t</i> -C ₄ H ₉ MgCl	27	15	+	276
CH ₃	H	C ₆ H ₅	H	<i>i</i> -C ₅ H ₁₁ MgBr	...	52*	...	277
CH ₃	H	C ₆ H ₅	H	C ₆ H ₅ MgI	+	4.9	...	111
CH ₃	H	C ₆ H ₅	H	(CH ₂) ₅ CHMgBr	trace	64.4	...	278
CH ₃	H	<i>n</i> -C ₆ H ₁₃	H	CH ₃ MgI	16	...	...	294
CH ₃	H	<i>n</i> -C ₆ H ₁₃	H	C ₂ H ₅ MgBr	+	...	...	294
CH ₃	H	<i>n</i> -C ₆ H ₁₃	H	<i>i</i> -C ₅ H ₁₁ MgBr	+	...	...	294
CH ₃	H	2-HOC ₆ H ₄	H	CH ₃ MgI	...	18.2	...	273
CH ₃	H	4-CH ₃ OC ₆ H ₄	H	C ₂ H ₅ MgBr	+	61.2	...	111
CH ₃	H	4-CH ₃ OC ₆ H ₄	H	(CH ₂) ₅ CHMgBr	+	70.2	...	278
CH ₃	H	C ₆ H ₅ CH=CH	H	C ₆ H ₅ CH ₂ MgCl	+†	...	...	329
CH ₃	H	Mes†	H	RMgX	+	+	...	401
CH ₃	H	ψ -C ₉ H ₁₅ §	H	(—CH ₂ CH ₂ MgBr) ₂	+	...	...	634
CH ₃	H	ψ -C ₉ H ₁₅ §	H	CH ₃ O(CH ₂) ₃ MgBr	53.5	...	...	409
CH ₃	H	ψ -C ₉ H ₁₅ §	H	C ₂ H ₅ O(CH ₂) ₃ MgBr	52	...	...	409
CH ₃	H	ψ -C ₉ H ₁₅ §	H	C ₆ H ₅ O(CH ₂) ₃ MgBr	49	...	...	409
CH ₃	H	α -C ₉ H ₁₅ ¶	H	H ₂ C=CHCH ₂ MgBr	ca. 65	...	...	635
CH ₃	H	α -C ₉ H ₁₅ ¶	H	CH ₃ CH=C(CH ₃)CH=CHCH ₂ MgBr	+	...	...	95
CH ₃	H	β -C ₉ H ₁₅ ¶	H	MgBr				
CH ₃	H	β -C ₉ H ₁₅ ¶	H	H ₂ C=CHC≡CMgBr	59	...	...	636, 637

* The abstract reports a 6-octanone, but this is obviously a misprint.

† The yield of diene is described as "poor."

‡ Mes = mesityl = 2,4,6-(CH₃)₃C₆H₂—.

§ The ketone is pseudoionone; ψ -C₉H₁₅ = (CH₃)₂C=CHCH₂CH₂C(CH₃)=CH.

¶ The ketone is α -ionone; α -C₉H₁₅ = 2,4,4-trimethylcyclohexen-3-yl.

‡ The ketone is β -ionone; β -C₉H₁₅ = 1,3,3-trimethylcyclohexen-2-yl.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
CH ₃	H	β -C ₉ H ₁₅ *	H	C ₂ H ₅ OC \equiv CMgBr	73	...	...	233,487
CH ₃	H	β -C ₉ H ₁₅ *	H	(=CHCH ₂ MgBr) ₂	+	...	...	638
CH ₃	H	β -C ₉ H ₁₅ *	H	H ₂ C=C(CH ₃)C \equiv CMgBr	48	...	...	636
CH ₃	H	β -C ₉ H ₁₅ *	H	CH ₃ CH=C(CH ₃)C \equiv CMgBr	52	...	...	636
CH ₃	H	β -C ₉ H ₁₅ *	H	(C ₂ H ₅ O) ₂ CHCH ₂ MgBr	64	...	...	639
C ₂ H ₅	H	CH ₃	H	C ₂ H ₅ MgBr	≤ 32.3 x†	67.7 x†	...	622
C ₂ H ₅	H	CH ₃	H	<i>i</i> -C ₃ H ₇ MgBr	≤ 19.8 x†	80.2 x†	...	622
C ₂ H ₅	H	CH ₃	H	<i>t</i> -C ₄ H ₉ MgCl	≤ 33.7 x†	66.3 x†	...	622
C ₂ H ₅	H	<i>n</i> -C ₃ H ₇	H	C ₂ H ₅ MgBr	38.6	...	...	184
C ₂ H ₅	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	+	71.0	...	111
C ₂ H ₅	H	C ₆ H ₅	H	<i>i</i> -C ₄ H ₉ MgBr	+	58.9	...	111
C ₂ H ₅	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	+	40.0	...	111
C ₂ H ₅	H	C ₆ H ₅	H	(CH ₂) ₅ CHMgBr	+	70.4	...	278
<i>n</i> -C ₃ H ₇	H	(C ₂ H ₅) ₂ N	H	C ₂ H ₅ MgBr	...	+†	...	153
<i>i</i> -C ₃ H ₇	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	0	90.2	...	111
<i>i</i> -C ₃ H ₇	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	<i>ca.</i> 9	86.6	...	111
<i>t</i> -C ₄ H ₉	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	0	98.1	...	111
<i>t</i> -C ₄ H ₉	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	0	96.9	...	111
4-BrC ₆ H ₄	H	α -C ₄ H ₃ O§	H	C ₂ H ₅ MgBr	...	95.0	...	346
4-BrC ₆ H ₄	H	α -C ₄ H ₃ O§	H	<i>n</i> -C ₃ H ₇ MgBr	...	80.0	...	346
4-BrC ₆ H ₄	H	α -C ₄ H ₃ O§	H	C ₆ H ₅ MgBr	...	85.0	...	346
4-BrC ₆ H ₄	H	C ₆ H ₅	H	(CH ₂) ₄ CHMgBr	...	48.0	...	452

* The ketone is β -ionone; β -C₉H₁₅ = 1,3,3-trimethylcyclohexen-2-yl.

† For the series of reactions studied, *x* is said to range from 0.86 to 1.00.

‡ This reaction is accompanied by cleavage; the product is *n*-C₃H₇COCH=CHR, where R is the organic radical of the Grignard reagent (RMgX).

§ The ketone is furfurylidene-*p*-bromoacetophenone; α -C₄H₃O = 2-furyl.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
4-BrC ₆ H ₄	H	C ₆ H ₅	H	4-BrC ₆ H ₄ MgBr	...	38.6	...	453
4-BrC ₆ H ₄	H	4-BrC ₆ H ₄ CO	H	C ₆ H ₅ MgBr	...	53.0	...	488
4-BrC ₆ H ₄	H	C ₆ H ₅ CH=CH	H	C ₆ H ₅ CH ₂ MgCl	...	+	...	506
4-ClC ₆ H ₄	H	α -C ₄ H ₃ O*	H	C ₂ H ₅ MgBr	...	95.0	...	346
4-ClC ₆ H ₄	H	α -C ₄ H ₃ O*	H	<i>n</i> -C ₃ H ₇ MgBr	...	72.0	...	347
4-ClC ₆ H ₄	H	α -C ₄ H ₃ O*	H	C ₆ H ₅ MgBr	...	94.0	...	347
4-ClC ₆ H ₄	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	...	66.9	...	453
C ₆ H ₅	H	CCl ₃	H	C ₆ H ₅ MgBr	...	93.0	...	111
C ₆ H ₅	H	CO ₂ H	H	C ₂ H ₅ MgBr	...	+	...	274
C ₆ H ₅	H	CO ₂ H	H	C ₆ H ₅ MgBr	...	22.5	...	274
C ₆ H ₅	H	CO ₂ H	H	4-CH ₃ OC ₆ H ₄ MgBr	...	22.0	...	274
C ₆ H ₅	H	CH ₃	H	CH ₃ MgI	0	+	...	256
C ₆ H ₅	H	CH ₃	H	C ₆ H ₅ MgBr	0	+	...	256
C ₆ H ₅	H	(CH ₃) ₂ N	H	C ₂ H ₅ MgBr	...	†	...	153
C ₆ H ₅	H	(CH ₃) ₂ N	H	C ₆ H ₅ MgBr	...	†	...	153
C ₆ H ₅	H	α -C ₄ H ₃ O†	H	RMgX§	...	+	...	624
C ₆ H ₅	H	C ₆ H ₅	H	CH ₃ MgBr	...	55-56	37-39	611
C ₆ H ₅	H	C ₆ H ₅	H	CH ₃ MgI	†	+	...	108
C ₆ H ₅	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	...	58.2	+	449,464
C ₆ H ₅	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	trace	95.8	...	111,147
C ₆ H ₅	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	27.1	35.1	...	454

* The ketone is furfurylidene-*p*-chloroacetophenone; α -C₄H₃O = 2-furyl.

† This addition is accompanied by cleavage; the product is C₆H₅COCH=CHR, where R is the organic radical of the Grignard reagent (RMgX).

‡ The ketone is α -furfurylideneacetophenone; α -C₄H₃O = 2-furyl.

§ RMgX = CH₃MgI, C₂H₅MgBr, C₆H₅MgBr.

¶ Major product.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
C ₆ H ₅	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	ca. 40	ca. 60	...	611
C ₆ H ₅	H	C ₆ H ₅	H	H ₂ C=CHCH ₂ MgBr	18.7	...	...	599
C ₆ H ₅	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	+	...	...	455
C ₆ H ₅	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	3.6	85.2	...	111, 147, 449, 464, 569, 611
C ₆ H ₅	H	C ₆ H ₅	H	(CH ₂) ₅ CHMgBr	ca. 5	ca. 95	...	278
C ₆ H ₅	H	C ₆ H ₅	H	4-CH ₃ C ₆ H ₄ MgBr	...	+	...	449
C ₆ H ₅	H	C ₆ H ₅	H	4-CH ₃ OC ₆ H ₄ MgBr	...	+	...	449
C ₆ H ₅	H	C ₆ H ₅	H	4-(CH ₃) ₂ NC ₆ H ₄ MgI	...	71.0	...	465
C ₆ H ₅	H	C ₆ H ₅	H	1-C ₁₀ H ₇ MgBr	...	+	...	275
C ₆ H ₅	H	2-HOC ₆ H ₄	H	C ₆ H ₅ MgBr	...	80.0*	...	438
C ₆ H ₅	H	2-HOC ₆ H ₄	H	4-CH ₃ C ₆ H ₄ MgBr	...	61.0†	...	438
C ₆ H ₅	H	C ₆ H ₅ SO ₂	H	C ₆ H ₅ MgBr	+	...	...	653
C ₆ H ₅	H	(CH ₂) ₅ CH	H	C ₂ H ₅ MgBr	...	+	...	278
C ₆ H ₅	H	(CH ₂) ₅ CH	H	C ₆ H ₅ MgBr	trace	+	...	278
C ₆ H ₅	H	4-CH ₃ OC ₆ H ₄	H	C ₂ H ₅ MgBr	+	93.2	...	111
C ₆ H ₅	H	4-CH ₃ OC ₆ H ₄	H	C ₆ H ₅ MgBr	1.6	95.7	...	111
C ₆ H ₅	H	3,4-CH ₂ O ₂ C ₆ H ₃	H	CH ₃ MgI	...	39.3	+	449
C ₆ H ₅	H	3,4-CH ₂ O ₂ C ₆ H ₃	H	C ₂ H ₅ MgBr	...	+	...	449
C ₆ H ₅	H	3,4-CH ₂ O ₂ C ₆ H ₃	H	C ₆ H ₅ MgBr	...	+	...	449
C ₆ H ₅	H	C ₆ H ₅ CO	H	C ₆ H ₅ MgBr	...	60-65	...	488, 641
C ₆ H ₅	H	C ₆ H ₅ CH=CH	H	C ₂ H ₅ MgBr	...	+	...	507
C ₆ H ₅	H	C ₆ H ₅ CH=CH	H	C ₆ H ₅ MgBr	...	73.1	...	507

* The product reported is 2,4-diphenyl-2-chromanol.

† The product reported is 2-phenyl-4-*p*-tolyl-2-chromanol.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
C ₆ H ₅	H	C ₆ H ₅ CH=CH	H	C ₆ H ₅ CH ₂ MgCl	...	+	...	507
C ₆ H ₅	H	4-(CH ₃) ₂ NC ₆ H ₄	H	C ₆ H ₅ MgBr	...	66.0	...	465
(CH ₂) ₅ CH	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	0	+	...	278
(CH ₂) ₅ CH	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	trace	+	...	278
4-CH ₃ C ₆ H ₄	H	CO ₂ H	H	C ₆ H ₅ MgBr	...	27.2	...	274
4-CH ₃ C ₆ H ₄	H	α -C ₄ H ₃ O*	H	CH ₃ MgI	...	50.0	...	346
4-CH ₃ C ₆ H ₄	H	α -C ₄ H ₃ O*	H	C ₂ H ₅ MgBr	...	70.0	...	346
4-CH ₃ C ₆ H ₄	H	α -C ₄ H ₃ O*	H	<i>i</i> -C ₃ H ₇ MgBr	...	80.0	...	346
4-CH ₃ C ₆ H ₄	H	α -C ₄ H ₃ O*	H	<i>i</i> -C ₄ H ₉ MgBr	...	70.0	...	346
4-CH ₃ C ₆ H ₄	H	α -C ₄ H ₃ O*	H	C ₆ H ₅ MgBr	...	80.0	...	346
4-CH ₃ C ₆ H ₄	H	2-HOC ₆ H ₄	H	C ₆ H ₅ MgBr	...	†	...	438
4-CH ₃ OC ₆ H ₄	H	α -C ₄ H ₃ O†	H	C ₂ H ₅ MgBr	...	73.3	...	347
4-CH ₃ OC ₆ H ₄	H	α -C ₄ H ₃ O†	H	<i>n</i> -C ₃ H ₇ MgBr	...	67.0	...	347
4-CH ₃ OC ₆ H ₄	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	trace	94.4	...	111
4-CH ₃ OC ₆ H ₄	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	trace	96.2	...	111
4-CH ₃ OC ₆ H ₄	H	4-CH ₃ OC ₆ H ₄	H	CH ₃ MgI	...	45.0	...	513
4-CH ₃ OC ₆ H ₄	H	4-CH ₃ OC ₆ H ₄	H	C ₂ H ₅ MgBr	...	80.0	...	513
4-CH ₃ OC ₆ H ₄	H	4-CH ₃ OC ₆ H ₄	H	<i>n</i> -C ₃ H ₇ MgBr	...	80.0	...	513
4-CH ₃ OC ₆ H ₄	H	4-CH ₃ OC ₆ H ₄	H	<i>i</i> -C ₃ H ₇ MgBr	...	75.0	...	513, 514
4-CH ₃ OC ₆ H ₄	H	4-CH ₃ OC ₆ H ₄	H	<i>n</i> -C ₄ H ₉ MgBr	...	70.0	...	513
4-CH ₃ OC ₆ H ₄	H	4-CH ₃ OC ₆ H ₄	H	<i>n</i> -C ₅ H ₁₁ MgBr	...	75.0	...	513
4-CH ₃ OC ₆ H ₄	H	4-CH ₃ OC ₆ H ₄	H	C ₆ H ₅ MgBr	...	75.0	...	513
4-CH ₃ OC ₆ H ₄	H	4-CH ₃ OC ₆ H ₄	H	(CH ₂) ₅ CHMgCl	...	85.0	...	514

* The ketone is α -furfurylidene-*p*-methylacetophenone; α -C₄H₃O = 2-furyl.

† The product reported is 2-*p*-tolyl-4-phenyl-2-chromanol.

‡ The ketone is α -furfurylidene-*p*-methoxyacetophenone; α -C₄H₃O = 2-furyl.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
4-CH ₃ OC ₆ H ₄	H	4-CH ₃ OC ₆ H ₄	H	C ₆ H ₅ CH ₂ MgCl	...	70.0	...	513
4-CH ₃ OC ₆ H ₄	H	4-CH ₃ OC ₆ H ₄	H	4-CH ₃ OC ₆ H ₄ MgBr	...	70.0	...	513
4-CH ₃ OC ₆ H ₄	H	C ₆ H ₅ CH=CH	H	C ₆ H ₅ CH ₂ MgCl	...	+	...	506
C ₆ H ₅ CH=CH	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	...	90.4	...	111
C ₆ H ₅ CH=CH	H	C ₆ H ₅	H	<i>t</i> -C ₄ H ₉ MgCl	...	76.1	...	276
C ₆ H ₅ CH=CH	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	...	78.8	...	111
C ₆ H ₅ CH=CH	H	C ₆ H ₅	H	C ₆ H ₅ C≡CMgBr	?	...	...	367
Mes*	H	CH ₃	H	Mes-MgBr*	...	70.0	...	393
Mes*	H	CH ₃ CH=CH	H	C ₆ H ₅ MgBr	...	81	...	640
Mes*	H	C ₆ H ₅	H	RMgX	0	+	...	401
Mes*	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	...	94	...	111, 539
Mes*	H	C ₆ H ₅	H	Mes-MgBr*	...	+	...	393
Mes*	H	Mes*	H	RMgX	0	+	...	401
Mes*	H	Mes*	H	CH ₃ MgI	...	†	...	393
Mes*	H	Mes*	H	C ₆ H ₅ MgBr	...	+	...	393
Mes*	H	Mes*	H	Mes-MgBr*	...	46.0	...	393
Mes*	H	MesCO*	H	<i>t</i> -C ₄ H ₉ MgCl	...	50	...	576
Mes*	H	MesCO*	H	C ₆ H ₅ MgBr	...	59-60	...	488
Dur†	H	CH ₃ CH=CH	H	C ₆ H ₅ MgBr	...	73	...	640
C ₂ H ₅ (C ₆ H ₅)CHCH ₂	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	0	<i>ca.</i> 100	...	111
C ₂ H ₅ (C ₆ H ₅)CHCH ₂	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	<i>ca.</i> 7	90.4	...	111
(C ₆ H ₅) ₂ CHCH ₂	H	C ₆ H ₅	H	C ₂ H ₅ MgBr	0	100 (?)§	...	111

* Mes = mesityl = 2,4,6-(CH₃)₃C₆H₂—.

† The yield is reported as "high."

‡ Dur = duryl = 2,3,5,6-(CH₃)₄C₆H—.

§ The reported yield (in grams) may be a misprint; it constitutes somewhat more than 100% of the theoretically possible yield.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n (%)</u>	<u>1,4- Add'n (%)</u>	<u>Cond'n (%)</u>	<u>Ref.</u>
(C ₆ H ₅) ₂ CHCH ₂	H	C ₆ H ₅	H	C ₆ H ₅ MgBr	trace	46.4	...	111
CH ₃	H	CH ₃	CH ₃	CH ₃ MgBr	+	...	...	137,604
CH ₃	H	CH ₃	CH ₃	CH ₃ MgI	+	...	...	61
CH ₃	H	CH ₃	CH ₃	CH ₃ MgI	24.3	...	...	138,139
CH ₃	H	CH ₃	CH ₃	CH ₃ MgI	87.0	...	...	613
CH ₃	H	CH ₃	CH ₃	(≡CMgI) ₂	+	...	...	125
CH ₃	H	CH ₃	CH ₃	C ₂ H ₅ MgBr	+	...	...	111,140, 604
CH ₃	H	CH ₃	CH ₃	C ₂ H ₅ MgBr	50.9†	...	...	141
CH ₃	H	CH ₃	CH ₃	C ₂ H ₅ MgBr	17.3†	...	...	141
CH ₃	H	CH ₃	CH ₃	C ₂ H ₅ MgI	+	...	...	232
CH ₃	H	CH ₃	CH ₃	H ₂ C=CHCH ₂ MgBr	ca. 91	...	...	25,142, 143
CH ₃	H	CH ₃	CH ₃	H ₂ C=CHCH ₂ MgBr	75	...	...	599
CH ₃	H	CH ₃	CH ₃	<i>n</i> -C ₃ H ₇ MgBr	+	...	...	232,604
CH ₃	H	CH ₃	CH ₃	<i>i</i> -C ₃ H ₇ MgBr	+	...	...	144,604
CH ₃	H	CH ₃	CH ₃	H ₂ C=CHC≡CMgBr	40.0	...	...	40
CH ₃	H	CH ₃	CH ₃	<i>n</i> -C ₄ H ₉ MgBr	+	...	...	604
CH ₃	H	CH ₃	CH ₃	<i>n</i> -C ₄ H ₉ MgI	+	...	...	232
CH ₃	H	CH ₃	CH ₃	<i>i</i> -C ₄ H ₉ MgBr	+	...	...	604
CH ₃	H	CH ₃	CH ₃	<i>t</i> -C ₄ H ₉ MgCl	46	0	...	112,144

* The total yield of addition product on the basis of reacting ketone is not stated. From Raman spectra data, Dupont and Menut (137) conclude that mesityl oxide comprises about 80% CH₃COCH=C(CH₃)₂ and about 20% CH₃COCH₂C(CH₃)=CH₂. The addition product isolated was estimated to consist of 75–80% (CH₃)₂C=CHC(CH₃)₂OH and 20–25% H₂C=C(CH₃)CH₂C(CH₃)₂OH

† Reaction at –10°.

‡ Reaction at 15°.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
CH ₃	H	CH ₃	CH ₃	<i>n</i> -C ₅ H ₁₁ MgBr	+	...	...	604
CH ₃	H	CH ₃	CH ₃	<i>i</i> -C ₅ H ₁₁ MgBr	+	...	...	604, 145
CH ₃	H	CH ₃	CH ₃	<i>t</i> -C ₅ H ₁₁ MgCl	8.3	16.2	+	305
CH ₃	H	CH ₃	CH ₃	C ₆ H ₅ MgBr	40.1	...	+	146, 140, 147
CH ₃	H	CH ₃	CH ₃	<i>n</i> -C ₄ H ₉ C≡CMgBr	78.9	...	...	83
CH ₃	H	CH ₃	CH ₃	C ₆ H ₅ CH ₂ MgCl	+	...	...	148
CH ₃	H	CH ₃	CH ₃	C ₆ H ₅ CH(CO ₂ Na)MgCl*	+†	...	...	149
CH ₃	H*	CH ₃	CH ₃	9-Fluorenyl-MgBr	30	...	...	626
CH ₃	H	α -C ₄ H ₃ O†	CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	...	55	...	308
CH ₃	H	α -C ₄ H ₃ O†	CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	...	52	...	308
C ₂ H ₅	H	CH ₃	C ₂ H ₅	C ₂ H ₅ MgBr	31.5§	...	...	239
C ₂ H ₅	H	CH ₃	C ₂ H ₅	C ₂ H ₅ MgBr	52.9¶	...	...	184
C ₂ H ₅	H	CH ₃	C ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr	+	...	...	239
CH ₃ OCH ₂ CH ₂	H	CH ₃	CH ₃	CH ₃ MgI	31.4	...	...	245
(CH ₃) ₂ C=CH	H	CH ₃	CH ₃	CH ₃ MgI	2.5	...	...	138
(CH ₃) ₂ C=CH	H	CH ₃	CH ₃	C ₆ H ₅ CH ₂ MgCl	+	...	...	148
<i>t</i> -C ₄ H ₉	H	CH ₃	<i>t</i> -C ₄ H ₉	C ₂ H ₅ MgBr	70.0	...	...	150
C ₆ H ₅	H	CH ₃	CH ₃	C ₆ H ₅ MgBr	0	+	...	256
C ₆ H ₅	H	CH ₃	C ₆ H ₅	C ₂ H ₅ MgBr	...	44.1	...	111
C ₆ H ₅	H	CH ₃	C ₆ H ₅	C ₆ H ₅ MgBr	...	37.4	...	111

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

†The yield is reported as "good."

‡ α -C₄H₃O = 2-furyl.

§Reaction at room temperature.

¶Reaction at -14°.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
C ₆ H ₅	H	CH ₃	C ₆ H ₅	C ₆ H ₅ CH(CO ₂ Na)MgCl *	...	+	+	149
C ₆ H ₅	H	C ₂ H ₅ O	C ₆ H ₅	C ₂ H ₅ MgBr	+	+	...	147
C ₆ H ₅	H	C ₂ H ₅ O	C ₆ H ₅	C ₂ H ₅ MgBr†	+	...	...	147
C ₆ H ₅	H	C ₂ H ₅ O	C ₆ H ₅	C ₆ H ₅ MgBr‡	+	+	...	147
C ₆ H ₅	H	C ₅ H ₅	C ₆ H ₅	C ₂ H ₅ MgBr	+	15.0	...	111
C ₆ H ₅	H	C ₆ H ₅	C ₆ H ₅	C ₆ H ₅ MgBr	+	0	...	111,455
C ₆ H ₅	H	C ₆ H ₅	C ₆ H ₅ SO ₂	C ₆ H ₅ MgBr	+	...	...	654
C ₆ H ₅	H	C ₆ H ₅	C ₆ H ₅ CO	C ₆ H ₅ MgBr	...	ca. 80	...	602
Mes§	H	CH ₃	C ₆ H ₅	CH ₃ MgI	...	+	...	538
Mes§	H	CH ₃	C ₆ H ₅	C ₆ H ₅ MgBr	...	82.7¶	...	538
Mes§	H	<i>t</i> -C ₄ H ₉	MesCO§	C ₆ H ₅ MgBr	...	31¶	...	590
Mes§	H	<i>t</i> -C ₄ H ₉	MesCO§	C ₆ H ₅ MgBr	...	70**	...	590
Mes§	H	C ₆ H ₅	C ₆ H ₅	CH ₃ MgI	...	82.0	...	538
Mes§	H	C ₆ H ₅	C ₆ H ₅	C ₂ H ₅ MgBr	...	+	...	538
Mes§	H	C ₆ H ₅	C ₆ H ₅	C ₆ H ₅ MgBr	...	60.0	...	538
Mes§	H	C ₆ H ₅	MesCO§	<i>t</i> -C ₄ H ₉ MgCl	...	+	...	590
C ₆ H ₅	Mes§	H	H	C ₆ H ₅ MgBr	0	0	...	500

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

† Concentrated Grignard reagent solution.

‡ Dilute Grignard reagent solution.

§ Mes = mesityl = 2,4,6-(CH₃)₃C₆H₂—.

¶ On basis of ketone unrecovered.

‡ Addition of ketone to Grignard reagent solution at room temperature, ten minutes standing.

** Addition of ketone to Grignard reagent solution at 0°; fifteen minutes standing.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
Mes*	Mes*	H	H	CH ₃ MgI	...	+	...	575
Mes*	Mes*	H	H	C ₆ H ₅ MgBr	...	+	...	575
Idur†	Mes*	H	H	C ₆ H ₅ MgBr	...	+	...	575
Dur‡	Mes*	H	H	CH ₃ MgI	...	+	...	575
CH ₃	Br	C ₆ H ₅	H	C ₆ H ₅ MgBr	...	92.8	...	272
CH ₃	CH ₃	CH ₃	H	CH ₃ MgI	70.0	...	...	150
CH ₃	CH ₃	CH ₃	H	<i>n</i> -C ₄ H ₉ MgBr	+§	+§	...	150
CH ₃	CH ₃	(CH ₃) ₂ N	H	CH ₃ MgI	...	+¶	...	153
CH ₃	CH ₃	(CH ₃) ₂ N	H	C ₂ H ₅ MgBr	...	+¶	...	153
CH ₃	CH ₃	<i>n</i> -C ₃ H ₇	H	C ₂ H ₅ MgBr	+	+	...	150
CH ₃	<i>n</i> -C ₃ H ₇	C ₂ H ₅	H	C ₂ H ₅ MgBr	41.2	29.4	...	185
CH ₃	CO ₂ C ₂ H ₅	CH ₃	H	CH ₃ MgI	...	+	...	151
CH ₃	CO ₂ C ₂ H ₅	α-C ₄ H ₃ O‡	H	C ₂ H ₅ MgI	...	59.4	...	308
C ₆ H ₅	Br	C ₆ H ₅	H	C ₆ H ₅ MgBr	...	95.6	...	275
C ₆ H ₅	Br	C ₆ H ₅	H	4-CH ₃ C ₆ H ₄ MgBr	...	91.0	...	603
C ₆ H ₅	CH ₃	C ₂ H ₅	H	C ₆ H ₅ MgBr	...	+	...	147
C ₆ H ₅	CH ₃	C ₆ H ₅	H	CH ₃ MgI	91.0	...	...	490
C ₆ H ₅	CH ₃	C ₆ H ₅	H	C ₂ H ₅ MgBr	...	+	...	147
C ₆ H ₅	CH ₃	C ₆ H ₅	H	C ₆ H ₅ MgBr	...	+	...	569

* Mes = mesityl = 2,4,6-(CH₃)₃C₆H₂—.

† Idur = isoduryl = 2,3,4,6-(CH₃)₄C₆H—.

‡ Dur = duryl = 2,3,5,6-(CH₃)₄C₆H—.

§ The ratio of 1,2- to 1,4-addition product is reported to be about 77:23.

¶ This reaction involves cleavage; the product isolated is CH₃COC(CH₃)=CHR, in which R represents the organic radical of the Grignard reagent (RMgX).

‡ α-C₄H₃O = 2-furyl.

TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
C ₆ H ₅	(CH ₂) ₅ N	C ₆ H ₅	H	C ₆ H ₅ MgBr	...	61.0	...	559
C ₆ H ₅	C ₆ H ₅	C ₆ H ₅	H	CH ₃ MgI	54-63	...	...	591
C ₆ H ₅	C ₆ H ₅	C ₆ H ₅	H	C ₂ H ₅ MgBr	...	100*	...	645
C ₆ H ₅	C ₆ H ₅	C ₆ H ₅	11	C ₆ H ₅ MgBr	...	95.8	...	591
C ₆ H ₅	C ₆ H ₅	C ₆ H ₅	H	C ₆ H ₅ CH ₂ MgCl	...	25.7	...	435
4-CH ₃ OC ₆ H ₄	CH ₃	4-CH ₃ OC ₆ H ₄	H	CH ₃ MgI	+†	trace	...	518
4-CH ₃ OC ₆ H ₄	CH ₃	4-CH ₃ OC ₆ H ₄	H	C ₂ H ₅ MgBr	...	ca. 80	...	518
4-CH ₃ OC ₆ H ₄	CH ₃	4-CH ₃ OC ₆ H ₄	H	<i>n</i> -C ₃ H ₇ MgBr	...	ca. 80	...	518
4-CH ₃ OC ₆ H ₄	C ₂ H ₅	4-CH ₃ OC ₆ H ₄	H	CH ₃ MgI	+†	trace	...	518
4-CH ₃ OC ₆ H ₄	C ₂ H ₅	4-CH ₃ OC ₆ H ₄	H	C ₂ H ₅ MgBr	...	ca. 80	...	518
4-CH ₃ OC ₆ H ₄	C ₂ H ₅	4-CH ₃ OC ₆ H ₄	H	<i>n</i> -C ₃ H ₇ MgBr	...	ca. 80	...	518
4-CH ₃ OC ₆ H ₄	<i>n</i> -C ₃ H ₇	4-CH ₃ OC ₆ H ₄	H	CH ₃ MgI	+†	trace	...	518
4-CH ₃ OC ₆ H ₄	<i>n</i> -C ₃ H ₇	4-CH ₃ OC ₆ H ₄	H	C ₂ H ₅ MgBr	...	ca. 80	...	518
4-CH ₃ OC ₆ H ₄	<i>n</i> -C ₃ H ₇	4-CH ₃ OC ₆ H ₄	H	<i>n</i> -C ₃ H ₇ MgBr	...	ca. 80	...	518
Mes†	CH ₃	Mes†	H	Mes-MgBr†	...	46.0	...	393
Mes†	<i>n</i> -C ₄ H ₉	Mes†	H	C ₆ H ₅ MgBr	...	+	...	590
CH ₃	CH ₃	CH ₃	C ₂ H ₅	CH ₃ MgI	63.0	...	...	150
CH ₃	CH ₃	CH ₃	C ₂ H ₅	C ₂ H ₅ MgBr	60.0	...	...	150
CH ₃	CH ₃	CH ₃	C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	38.0	...	...	150
CH ₃	CH ₃	CH ₃	C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgBr	38.0	...	...	150
C ₆ H ₅	CH ₃	CH ₃	CO ₂ H	C ₆ H ₅ MgBr	...	85.5	...	332

* Either isomer of the unsaturated ketone (m., respectively, 88-89° or 102°) gives the same yield of saturated ketone in the same ratio of isomeric forms (m., respectively, 92° and 170°). The reported yields (in grams) are somewhat more than 100 percent of the theoretical.

† The principal products appear to be indenenes, which could arise only from 1,2-addition.

‡ Mes = mesityl = 2,4,6-(CH₃)₃C₆H₂—.

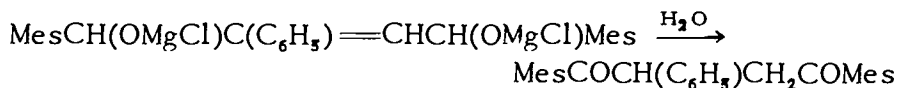
TABLE VI-XVI (Continued)

<u>R</u>	<u>R¹</u>	<u>R²</u>	<u>R³</u>	<u>R⁴MgX</u>	<u>1,2- Add'n</u> (%)	<u>1,4- Add'n</u> (%)	<u>Cond'n</u> (%)	<u>Ref.</u>
C ₆ H ₅	C ₄ H ₈ NO*	C ₄ H ₈ NO*	C ₆ H ₅	CH ₃ MgI	2.4	...	...	544
C ₆ H ₅	C ₆ H ₅	C ₆ H ₅	C ₆ H ₅	CH ₃ MgI	54-63	...	...	591
C ₆ H ₅	C ₆ H ₅	C ₆ H ₅	C ₆ H ₅	C ₆ H ₅ MgBr	31.9	37.3†	...	591
C ₆ H ₅	C ₆ H ₅	C ₆ H ₅	C ₆ H ₅ O	C ₆ H ₅ MgBr	70-90	...	...	602

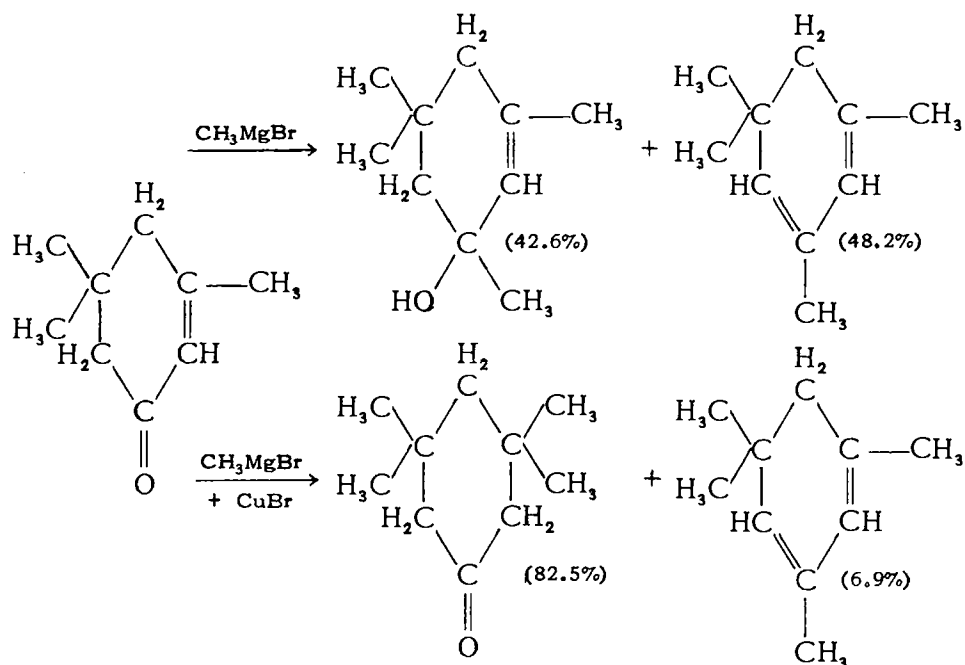
* C₄H₈NO = 4-morpholino.

† This 1,4-addition involves the aromatic nucleus rather than the olefinic double bond.

of the interaction of *t*-butylmagnesium chloride with 1-phenyl-1,2-dimesitoylethylene was the reduction product 1-phenyl-1,2-dimesitoylethane.



Facilitation of 1,4- at the expense of 1,2-addition. Due consideration should also be given to the fact that many of the earlier studies in this field necessarily employed metallic magnesium of a relatively low degree of purity. Although no exhaustive study of this subject has been made, the work of Kharasch and Tawney¹⁸⁶ has shown that the presence of metallic impurities may materially affect the ratios of 1,2- and 1,4-addition products. It was found, for example, that, when treated with methylmagnesium bromide prepared from highly purified magnesium,* isophorone yielded 90.8 percent of 1,2-addition products (carbinol and diene), with no 1,4-addition product detectable. The inclusion of as little as one mole percent of cuprous chloride† in the reaction mixture reduced the yield of 1,2-addition product (diene) to 6.9 percent and induced an 82.5 percent yield of 1,4-addition product. Metallic copper had a similar, though much less pronounced effect.



¹⁸⁶Kharasch and Tawney, *J. Am. Chem. Soc.*, 63, 2308-15 (1941).

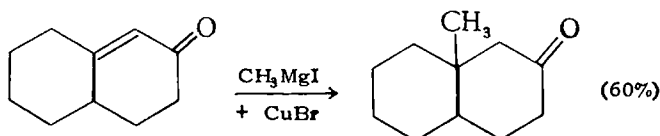
*Radio grade Mazlo rolled ribbon (99.98 percent Mg), supplied by the Aluminum Company of America. The impurities were stated to be 0.01-0.015 percent combined iron and aluminum, together with silicon and traces of copper and nickel.

†In the presence of an excess of Grignard reagent a cupric halide would, of course, have the same effect, for it would be reduced immediately to the cuprous salt.

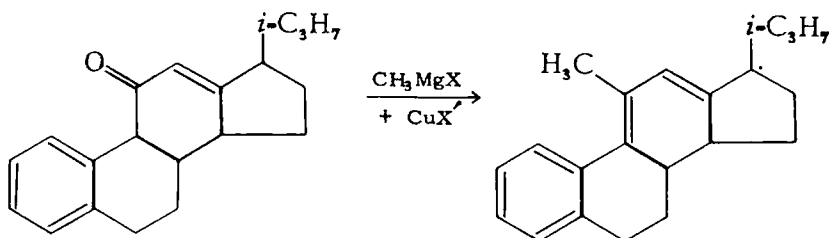
Ferric, nickelous, and cobaltous chlorides gave rise to other reactions which materially reduced the amount of, or completely superseded, the addition reactions.

Similar inductions of 1,4-additions with the aid of cuprous halides have been reported by Birch and Robinson¹⁸⁷ (carvone + CH_3MgI + CuBr), by Ruzicka *et al.*¹⁸⁸ (3-methyl-2-cyclohexen-1-one + CH_3MgI + CuCl), and by Stoll and Commarmont¹⁸⁹ (2-cyclopentadecen-1-one + CH_3MgBr + CuCl_2).

The possibility of inducing 1,4-addition at will suggests a new method for the introduction of angular methyl groups into polycyclic compounds, although this possibility may be limited by structural rigidity. In the relatively simple model experiment involving 4,4a,5,6,7,8-hexahydro-2(3*H*)-naphthalenone, methylmagnesium iodide, and cuprous bromide, Birch and Robinson (*loc. cit.*¹⁸⁷) obtained a 60 percent yield of *cis*-8a-methyloctahydro-2(1*H*)-naphthalenone.



With 17-isopropyl-6,7,8,14,16,17-hexahydro-15-cyclopenta [*a*] phenanthren-11(9*H*)-one, methylmagnesium bromide or iodide, and cuprous chloride or bromide; however, they were unsuccessful in introducing an angular methyl group at carbon atom 13, and isolated only the dehydrate of the 1,2-addition product.¹⁹⁰



The rationale of the cuprous halide induction of 1,4-addition can scarcely be said to have been unequivocally established, but the available evidence affords a basis for a reasonable working hypothesis. On the premise that 1,2- and 1,4-addition are (potentially, at least) competing reactions it would appear that the function of the cuprous halide might be either to facilitate 1,4-addition or to inhibit 1,2-addition. The Birch and Robinson experiments suggest the probability that the former

¹⁸⁷Birch and Robinson, *J. Chem. Soc.*, 1943, 501-2.

¹⁸⁸Büchi, Jeger, and Ruzicka, *Helv. Chim. Acta*, 31, 241-8 (1948).

¹⁸⁹Stoll and Commarmont, *Helv. Chim. Acta*, 31, 554-5 (1948).

¹⁹⁰Birch and Robinson, *J. Chem. Soc.*, 1944, 503-6.

is the case. Taken in conjunction with the well-known tendency of cuprous halides to form complexes with olefinic compounds,¹⁹¹ this probability lends credibility to the hypothesis that complex formation labilizes the carbon-to-carbon double bond in a manner that facilitates 1,4-addition.

Possibility of suppressing 1,2-addition. It seems logical to suppose that a similar end-result could be achieved by the suppression of 1,2-addition, as by the employment of a diorganocadmium reagent in place of the Grignard reagent. The 1,2-addition of a diorganocadmium compound to a carbonyl double bond either does not take place at all, or takes place so slowly as to be negligible in comparison with a competing reaction (see section on Preparation of Ketones, Chapter IX). That cadmium compounds are probably capable of 1,4-addition to α,β -unsaturated ketones is indicated by their analogous 1,4-addition in good yield to esters of the type $\text{RCH}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$.¹⁹² In especially refractory cases it might be found profitable both to suppress 1,2-addition (as by the use of a cadmium or zinc reagent) and to facilitate 1,4-addition (as by the aid of a cuprous halide).

Since the first draft of this discussion was written it has been reported by Wittig *et al.*¹⁹³ that, although diphenylcadmium reacts very slowly with benzylideneacetophenone at room temperature, it undergoes nearly quantitative 1,4-addition in eight hours at 100°. Gilman and Kirby¹⁹⁴ had previously reported 1,4-addition of diphenylzinc to benzylideneacetophenone in 91 percent yield.

Probable Mechanism of 1,4-Addition. There is little (or no) direct evidence on which to base a theory of the mechanism of the 1,4-addition of a Grignard reagent to an α,β -unsaturated carbonyl compound. In view, however, of the apparently satisfactory applicability of the concept of a quasi six-membered ring transition state to the elucidation of other Grignard reactions,* there is strong temptation to extend the notion somewhat farther. A speculation that appears fairly plausible in that it conflicts with none of the presently known facts may be diagrammatically presented as follows:

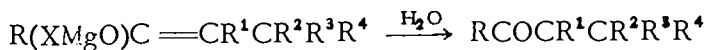
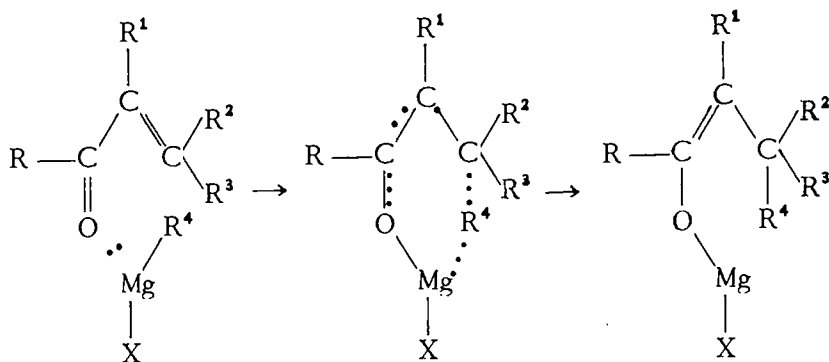
¹⁹¹For leading references see: Keller, *Chem. Revs.*, 28, 229-67 (1941); Gilliland, Bliss, and Kip, *J. Am. Chem. Soc.*, 63, 2088-90 (1941); Kepner and Andrews, *J. Org. Chem.*, 13, 208-13 (1948); Keefer, Andrews, and Kepner, *J. Am. Chem. Soc.*, 71, 2381-3 (1949).

¹⁹²Riegel, Siegel, and Lilienfeld, *J. Am. Chem. Soc.*, 68, 984-5 (1946).

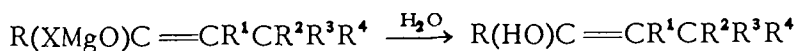
¹⁹³Wittig, Meyer, and Lange, *Ann.*, 571, 167-201 (1951).

¹⁹⁴Gilman and Kirby, *J. Am. Chem. Soc.*, 63, 2046-8 (1941).

*For example, the "normal" 1,2-addition at a carbonyl double bond, the Grignard reagent reduction of a carbonyl compound, the Meerwein reduction of a carbonyl compound by a halomagnesium alkoxide, and the Grignard enolization of a carbonyl compound.

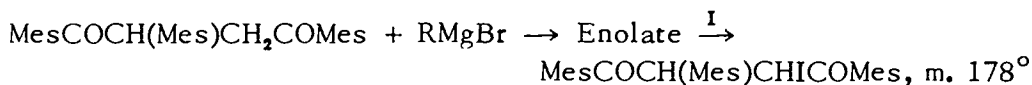
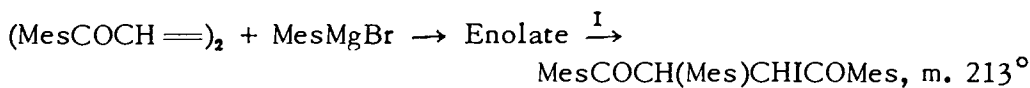


or



The product of a 1,4-addition of this kind is, of course, an enolate; whether the vinyl alcohol (*i.e.*, the enol) or the ketone is obtained on hydrolysis depends on the nature of the individual compound.

It may not be amiss to remind the reader that enolates derived by the 1,4-addition of Grignard reagents to α,β -unsaturated ketones appear to be stereoisomers of the structurally identical enolates derived by Grignard enolization of the related saturated ketones. An observation to this effect by Kohler *et al.* (*loc. cit.*¹⁷⁶) has already been cited in connection with the discussion of reductive enolization of α -halo ketones (*q.v.*). Lutz and Kibler¹⁹⁵ report a similar observation which may be summarized as follows:*



Essentially the mechanism suggested above has been proposed by Lutz and Reveley.¹⁹⁶ To this Alexander and Coraor¹⁹⁷ offer the objection that it cannot be a general one in that it does not appear to them to be applicable to the conjugate additions of 2-cyclohexen-1-one. "It is clear, however," they write, "that the cyclic, intramolecular process cannot be the only route leading to conjugate addition, for it has been reported that 2-cyclohexen-1-one undergoes conjugate addition with Grignard reagents, yet the distance between the carbonyl oxygen and the β -carbon atom of

¹⁹⁵Lutz and Kibler, *J. Am. Chem. Soc.*, 62, 360-72 (1940).

*Mes = mesityl = 2,4,6-(CH₃)₃C₆H₂—; R = CH₃, C₂H₅, C₆H₅.

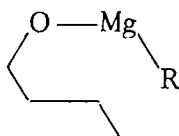
¹⁹⁶Lutz and Reveley, *J. Am. Chem. Soc.*, 63, 3180-9 (1941).

¹⁹⁷Alexander and Coraor, *J. Am. Chem. Soc.*, 73, 2721-3 (1951).

this compound appears to be too great to permit the formation of a complex such as [the quasi six-membered ring transition state] suggested."

Alexander and Coraor have further compared the 1,4-additions of ethyl, isopropyl, and *t*-butyl Grignard reagents to 2-cyclohexen-1-one and its open-chain analogs, 3-penten-2-one, 3-hexen-2-one, 4-hexen-3-one, and 3-hepten-2-one. Except for ethylmagnesium bromide, they found the relative proportions of 1,4-addition to 2-cyclohexen-1-one comparable to those of the 1,4-additions to its open-chain analogs. To them, "these results suggest that a possible path of reaction involving a cyclic intramolecular transition state is relatively unimportant."

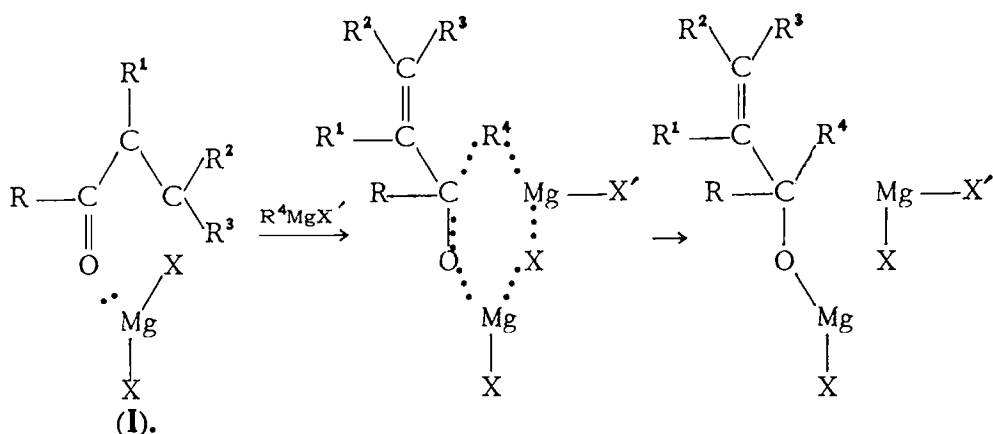
In the opinion of the present authors this argument implicitly attributes to the ketone-Grignard reagent complex a rigidity which it probably does not in fact possess. Undoubtedly Werner complex formation with the Grignard reagent would materially alter the character of the carbonyl double bond, and might reasonably be expected to enhance considerably its angular flexibility; probably some of this labilizing effect would be transmitted to the conjugated carbon-to-carbon double bond. If that bond were further labilized by complex formation, as with a cuprous halide, the entire structure might conceivably attain a flexibility comparable to that of, say, an organomagnesium derivative of cyclohexanol. According to the Sachse-Mohr theory, such a derivative could assume, at least momentarily, a configuration like that of the model projected in the following diagram.



Possible suppression of 1,4- in favor of 1,2-addition.* The working hypotheses tentatively proposed to account respectively for 1,4- and 1,2-additions suggest that it might be possible to suppress the former in favor of the latter by an experimental device analogous to that proposed for the suppression of Grignard reagent reduction in favor of "normal" addition.

If it were possible to form the initial Werner complex (I) with a metallic compound incapable of 1,4-addition (suitably MgX_2), and then to treat that complex with a Grignard reagent, 1,2-addition might be favored at the expense of 1,4-addition provided that complex exchange in the senses already defined were not too rapid.

*The practically equivalent facilitation of 1,2- at the expense of 1,4-addition might also be invoked by the use of the organo compound of a more "active" metal, as, *e.g.*, lithium or potassium, [see Gilman and Kirby, (*loc. cit.*¹⁹⁴)], although the possible introduction of new complications into the reaction precludes confident prediction of improved results in syntheses.



Such exchange might be minimized by saturating the Grignard reagent solution with magnesium halide (which is considerably more soluble in Grignard reagent solutions than in pure ether).

For highly "hindered" ketones (such as mesityl or duryl) 1,2-addition might still be very slow in comparison with complex exchange (and, therefore, in comparison with 1,4-addition). In intermediate cases, however, it should be possible to effect a material increase in the ratio of 1,2- to 1,4-addition.

Constitutional factors affecting order of addition. It would appear highly probable on *a priori* theoretical grounds that the nature of the unsaturated carbonyl compound should be the primary factor determining the order of addition, and the available data, insofar as they are decisive, support that view. It is, however, difficult to formulate any broad generalizations relating structural features to reactive behavior.

Kohler and Heritage¹⁹⁸ attempted a limited correlation of this sort, saying: "... the reaction between substances of this type [$C=C-C=O$] and organic magnesium compounds varies in a remarkable way with the atoms or groups in combination with the carbon atom of the carbonyl group. The reaction is always one of direct addition, but in the case of aldehydes and of those ketones that contain the group $-CH=CH-C(CH_3)=O$ the magnesium compound combines exclusively with the carbonyl group, while only 1,4-addition takes place when the ketone contains the group $-CH=CH-C(C_6H_5)=O$." The reactions of benzalacetone ($CH_3COCH=CHC_6H_5$) and of various of its derivatives have since been shown by Kohler and his students, as well as by others, to constitute glaring exceptions to one part of the foregoing statement, and the work of Stevens¹⁹⁹ on α,β -unsaturated aldehydes and of Kohler and others on benzalacetophenone suggest that the remainder be somewhat modified (see Table VI-XVI).

¹⁹⁸Kohler and Heritage, *Am. Chem. J.*, 33, 21-35 (1905).

¹⁹⁹Stevens, *J. Am. Chem. Soc.*, 57, 1112-7 (1935).

Colonge²⁰⁰ has offered a somewhat broader, but still empirical, summarization of the reported facts. With substitution of the conventional system of numbering for that employed by Colonge, his statement may be freely translated as follows.

“(a). If carbon atom number 4 of the conjugated system carries a second hydrocarbon substituent [*i.e.*, two substituents] there is no [1,4] addition of the Grignard reagent, but normal reaction at the carbonyl group [1,2-addition].

“(b). The presence of a substituent on carbon atom number 3 and the absence of a second substituent [*i.e.*, the presence of only one substituent] on carbon atom number 4 favors [1,4] addition to the conjugated system.

“(c). When there is a substituent on carbon atom number 3 and a second substituent [*i.e.*, two substituents] on carbon atom number 4, only normal [1,2] addition at the ketonic function is observed.

“(d). In the aliphatic series, under the most favorable conditions, addition to the conjugated system [1,4 addition] is never as important as normal addition to the carbonyl group [1,2 addition].”

The rules stated by Chelintsev and Till²⁰¹ are merely a partial paraphrase of those of Colonge.

In view of the fact that 1,2- and 1,4-additions may be regarded as competitive with each other (as well as with various side-reactions), the reactivity of the carbonyl group might reasonably be expected to play an important part in determining the order of addition. In α,β -unsaturated carbonyl compounds ($\text{RCOCR}^1=\text{CR}^2\text{R}^3$) the atom or radical R would naturally have a pronounced effect on the reactivity of the carbonyl group. The question then arises, whether this effect is predominantly steric or predominantly electronic.

If the effect be predominantly electronic the facts that aldehydes ($\text{R} = \text{H}$) are in general more reactive toward Grignard reagents than are ketones, and that methyl ketones ($\text{R} = \text{CH}_3$) are in general more reactive than aryl ketones [$\text{R} = \text{C}_6\text{H}_5$, 2,4,6- $(\text{CH}_3)_3\text{C}_6\text{H}_2$, etc.] would suggest that, the remainder of the molecule remaining substantially the same, the reactivity of the carbonyl group should increase as the “electronegativity” of R decreases,²⁰² and that 1,2-addition should be correspondingly favored.* Unfortunately no data are available for comparison of the behavior of

²⁰⁰Colonge, *Bull. soc. chim.*, [5], 2, 754-61 (1935).

²⁰¹Chelintsev and Till, *Uchenye Zapiski Saratov Gosudarst. Univ. N. G. Chernyshevskogo, Khim.*, 15, No. 4, 24-31 (1940); *Chem. Abstr.*, 35, 6953 (1941).

²⁰²Concerning the relative electronegativities of organic radicals see: Kharasch and Reinmuth, *J. Chem. Education*, (a) 5, 404-18 (1928); (b) 8, 1703-48 (1931); Kharasch, Reinmuth, and Mayo, *ibid.*, (c) 11, 82-96 (1934); (d) 13, 7-19 (1936).

*These conclusions appear to be fully substantiated by the relative reactivity studies of Hibbert, *J. Chem. Soc.*, 101, 341-4 (1912), and Lewis and Wright, *J. Am. Chem. Soc.*, 74, 1257-9 (1952).

3-pentene-2-one ($\text{CH}_3\text{COCH}=\text{CHCH}_3$) and 5,5-dimethyl-2-hexen-4-one ($t\text{-C}_4\text{H}_9\text{COCH}=\text{CHCH}_3$). With both benzalacetone ($\text{CH}_3\text{COCH}=\text{CHC}_6\text{H}_5$) and benzalpinacolin ($t\text{-C}_4\text{H}_9\text{COCH}=\text{CHC}_6\text{H}_5$) 1,4-addition appears to predominate.

If, on the other hand, the effect be predominantly steric, one must conclude that the bulkier the group R the less the reactivity of the carbonyl group, the greater the inhibition of 1,2-addition, and to the extent that suppression of one competing reaction affects the issue, the greater the tendency to 1,4-addition.

There remains the possibility that steric and electronic influences are effective in similar degree, in which case they may reinforce each other, as when $\text{R} = \text{mesityl}$ [$2,4,6\text{-(CH}_3)_3\text{C}_6\text{H}_2$], or operate in opposition to each other, as when $\text{R} = t\text{-butyl}$. The available information justifies no conclusions.

As regards 1,2-addition, the electronic effect of a substituent on carbon atom number 3 (R^1), either activating or deactivating, might be expected to be relatively minor, whereas the steric effect (which could be inhibitory only) might be considerable. As regards 1,4-addition, involving the union of a negative ion with an olefinic carbon atom, R^1 might exert an inhibitory steric effect and, depending upon its nature, an activating or deactivating electronic effect. Regarding the net outcome the experimental evidence is fragmentary and conflicting, Colonge's rule notwithstanding.

As regards 1,2-addition, substitution on carbon atom number 4 (R^1, R^2) might be expected to exert a relatively minor electronic effect (either activating or deactivating) and a negligible (inhibitory) steric effect. As regards 1,4-addition, both electronic effects (either activating or deactivating, depending upon the nature of the substituents) and steric (inhibitory) effects are to be expected. On the basis of the available evidence (inadequate, it is true), the steric effect would appear to predominate. Mesityl oxide [$\text{CH}_3\text{COCH}=\text{C}(\text{CH}_3)_2$] appears to undergo 1,2-addition chiefly, whereas with benzalacetone ($\text{CH}_3\text{COCH}=\text{CHC}_6\text{H}_5$) 1,4-addition appears to predominate. The activating electronic effect of two methyl groups attached to an olefinic carbon atom is nearly, though probably not quite altogether, equal to that of one phenyl group. The inhibiting steric effect is undoubtedly greater.

The results of a comparative study of the reactions of various organometallic compounds with benzalacetophenone by Gilman and Kirby²⁰³ are summarized in part as follows. "With benzalacetophenone the less reactive phenylmetallic compounds of beryllium, magnesium, zinc, and manganese show predominantly, if not exclusively, 1,4-addition. The highly reactive compounds of potassium and calcium show 1,2-addition. The organometallic compounds of intermediate activity (sodium and lithium) show both 1,2- and 1,4-addition."

²⁰³Gilman and Kirby, *J. Am. Chem. Soc.*, 63, 2046-8 (1941).

This suggests that for some α,β -unsaturated carbonyl compounds at least the nature of the Grignard reagent employed might affect to some extent the order of addition. For compounds which show both 1,2- and 1,4-addition it might be expected that the more reactive²⁰⁴ of two Grignard reagents would undergo the higher ratio of 1,2- to 1,4-addition. In the only relevant study reported,²⁰⁵ the ratio of 1,4- to 1,2-addition for a series of unsaturated ketones appeared to be higher for the somewhat more reactive ethylmagnesium bromide than for phenylmagnesium bromide. However, in view of the facts that all byproducts were ignored, and that only the ratios of 1,4- to 1,2-addition products actually isolated were determined, this study can scarcely be regarded as critical.

On the whole, despite the apparent wealth of experimental data (see Table VI-XVI), knowledge of the factors determining the order of addition of Grignard reagents to conjugated carbonyl systems is unsatisfactorily meager.

The reaction mechanisms proposed as working hypotheses describe 1,2-addition as trimolecular (involving one molecule of carbonyl compound and two molecules of Grignard reagent), whereas 1,4-addition is assumed to be bimolecular (involving one molecule each of carbonyl compound and Grignard reagent). This suggests that the concentration of Grignard reagent employed might affect the relative proportions of 1,2- and 1,4-addition products formed. To the best knowledge of the present authors no systematic investigation on this point has been undertaken, but Reynolds²⁰⁶ has reported that treatment of the ethyl enol ether of dibenzoylmethane $[C_6H_5COCH=C(OC_2H_5)C_6H_5]$ with a "concentrated" solution of phenylmagnesium bromide yields the 1,2-addition product only, whereas the use of a "dilute" Grignard reagent solution leads to the formation of both 1,2- and 1,4-addition products.

The proposal previously made as to the possibility of suppressing 1,4- in favor of 1,2-addition implies that the magnesium halide content of a Grignard reagent solution might affect the relative proportions of 1,2- and 1,4-addition products formed in reactions with conjugated carbonyl systems. Because the excess magnesium halide content of a specific Grignard reagent may vary within wide limits depending upon the method of preparation and the quality of the magnesium used, because the tendency to Wurtz byproduct formation in Grignard reagent preparation varies considerably from halide to halide, and because the Schlenk equilibrium point appears to vary from Grignard reagent to Grignard reagent, it would seem desirable to approach the question of the effects of constitution on the direction of addition to conjugated carbonyl systems by way of the

²⁰⁴Concerning relative reactivities of Grignard reagents with respect to "normal" (*i.e.*, 1,2-) addition to a carbonyl group see: Kharasch and Weinhouse, *J. Org. Chem.*, **1**, 209-30 (1936).

²⁰⁵Kohler, *Am. Chem. J.*, **38**, 511-61 (1907).

²⁰⁶Reynolds, *Am. Chem. J.*, **44**, 305-31 (1910).

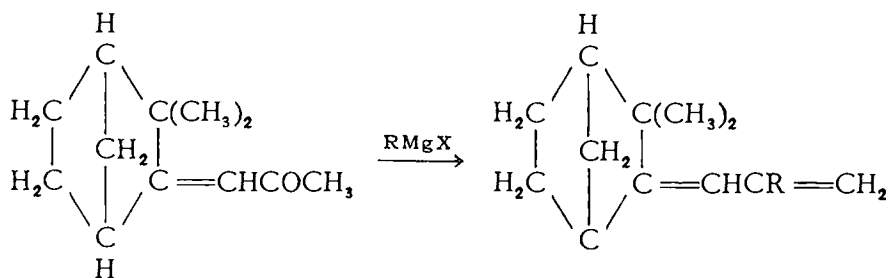
diorganomagnesium compounds. (Supplementary studies with reagents of varying, but definitely known, halide contents would also be of interest.)

That there may be a considerable difference in the temperature gradients of the 1,2- and 1,4-addition reactions is suggested by the report of Lutz Reveley²⁰⁷ that 1-*t*-butyl-1,2-dimesitylolethylene reacts with mesitylmagnesium bromide at room temperature to give 31 percent of 1,4-addition product, whereas the yield at 0° was 70 percent. Temperature control is therefore indicated unless preliminary experiments show it to be unnecessary.

Obviously, it would be wise to avoid unnecessary complications by employing non-reducing Grignard reagents. A possible series that would include a considerable range of radical electronegativities, as well as radical sizes might comprise mesityl, phenyl, methyl, neopentyl, and benzyl reagents. For comparative purposes it would be desirable that all reactions be run at the highest attainable common Grignard reagent concentration and at some considerably lower common concentration, or with "normal" and "inverse" order of addition.

One careful quantitative study of the reactions of such a series of diorganomagnesium compounds with a series of twelve or fifteen intelligently selected ketones would contribute more to understanding of the subject than have all the reported observations of the past half-century.

Among the 1,2-additions not listed in Table VI-XVI are those of methylmagnesium iodide and phenylmagnesium bromide to ω -acetylcamphene, reported by Lipp and Quadevlieg.²⁰⁸ The products isolated were the dienes.

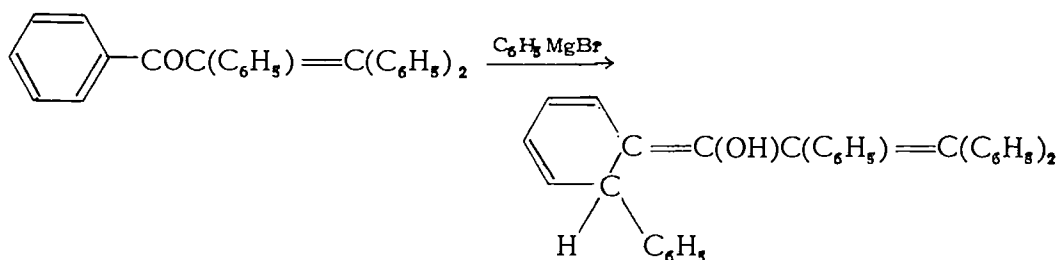


Of special interest are the reactions of diphenylbenzalacetophenone, as reported by Kohler and Nygaard.²⁰⁹ This ketone does not react with Grignard reagents in ethyl ether solution even under prolonged reflux. In benzene, at higher temperatures, methylmagnesium iodide gives 1,2-addition products, whereas phenylmagnesium bromide gives, in part, 1,2-addition products, and, in part, a 1,4-addition product. It is remarkable that, although there is an olefinic double bond conjugated with the carbonyl group, the 1,4-addition involves the aromatic ring.

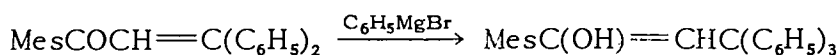
²⁰⁷Lutz and Reveley, *J. Am. Chem. Soc.*, 63, 3178-80 (1941).

²⁰⁸Lipp and Quadevlieg, *Ber.*, 62B, 2311-22 (1929).

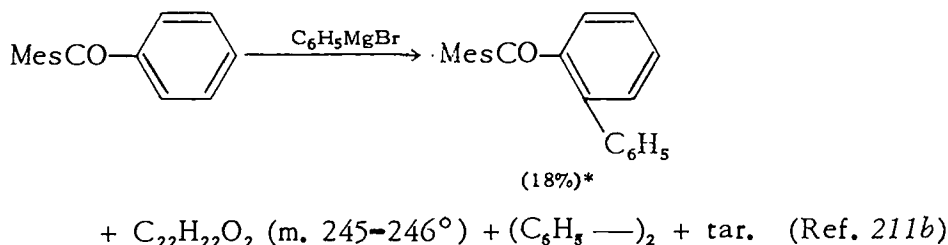
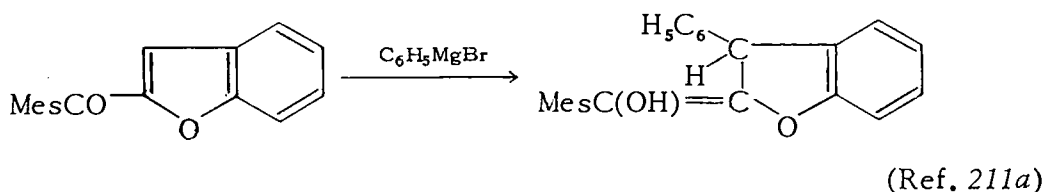
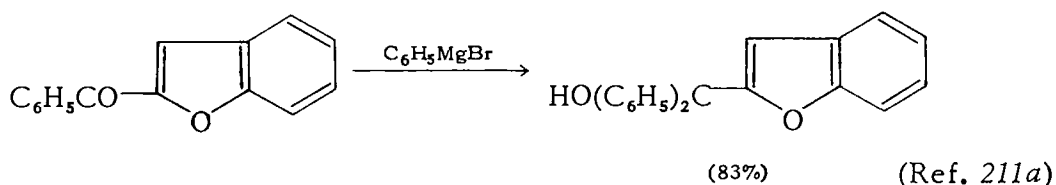
²⁰⁹Kohler and Nygaard, *J. Am. Chem. Soc.*, 52, 4128-39 (1930). See also: Kharasch and Sayles, *J. Am. Chem. Soc.*, 64, 2972-4 (1942).



It would be interesting to know whether or not cuprous halide labilization of the olefinic double would suffice to alter the direction of addition in this case. (If desired, 1,2-addition could be suppressed by use of the cadmium reagent.) Unquestionably 4,4-diphenyl substitution is sterically inimical to the olefinic 1,4-addition, but that it does not constitute an insuperable barrier thereto is demonstrated by the behavior of benzhydrylideneacetomesitylene, as reported by Kohler and Barnes.²¹⁰



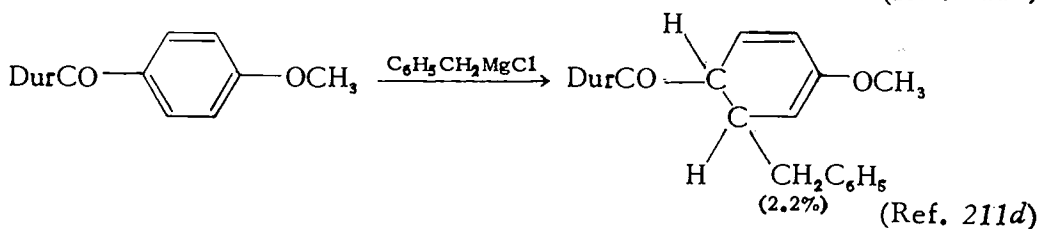
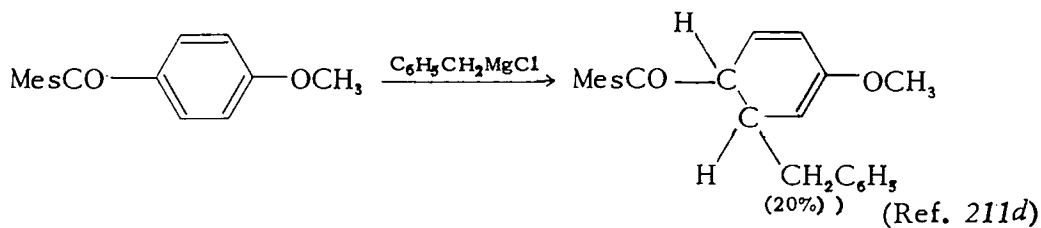
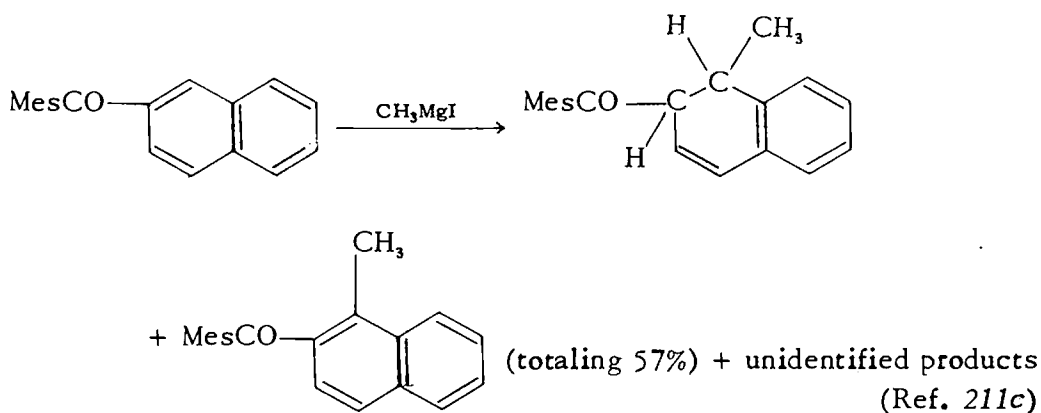
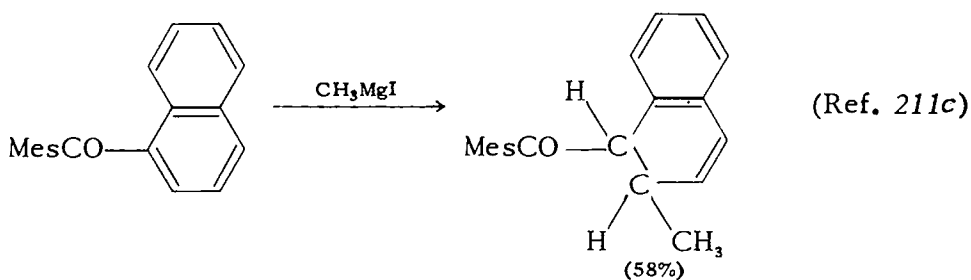
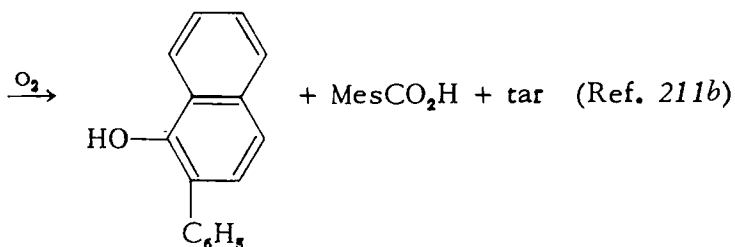
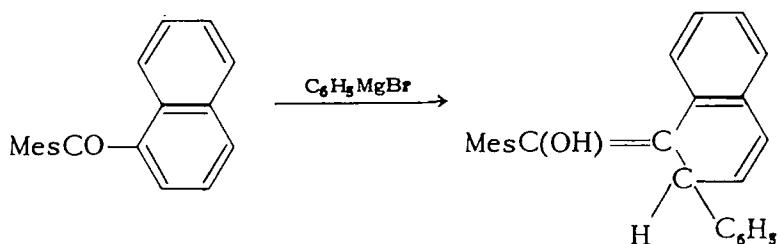
Fuson *et al.*²¹¹ have also reported 1,4-additions involving aromatic rings, in cases, however, in which there is no olefinic double bond in conjugation with the carbonyl group.



²¹⁰Kohler and Barnes, *J. Am. Chem. Soc.*, 55, 690–5 (1933).

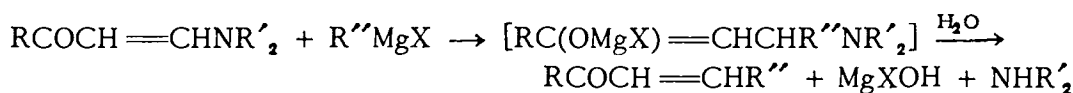
²¹¹(a) Fuson, Kaiser, and Speck, *J. Org. Chem.*, 6, 845–51 (1941); (b) Fuson, Armstrong, and Speck, *J. Org. Chem.*, 7, 297–302 (1942); (c) Fuson, McKusick, and Spangler, *J. Am. Chem. Soc.*, 67, 597–601 (1945); (d) Fuson and Gaertner, *J. Org. Chem.*, 13, 496–501 (1948).

*Presumably by atmospheric oxidation of the dihydro derivative originally formed.

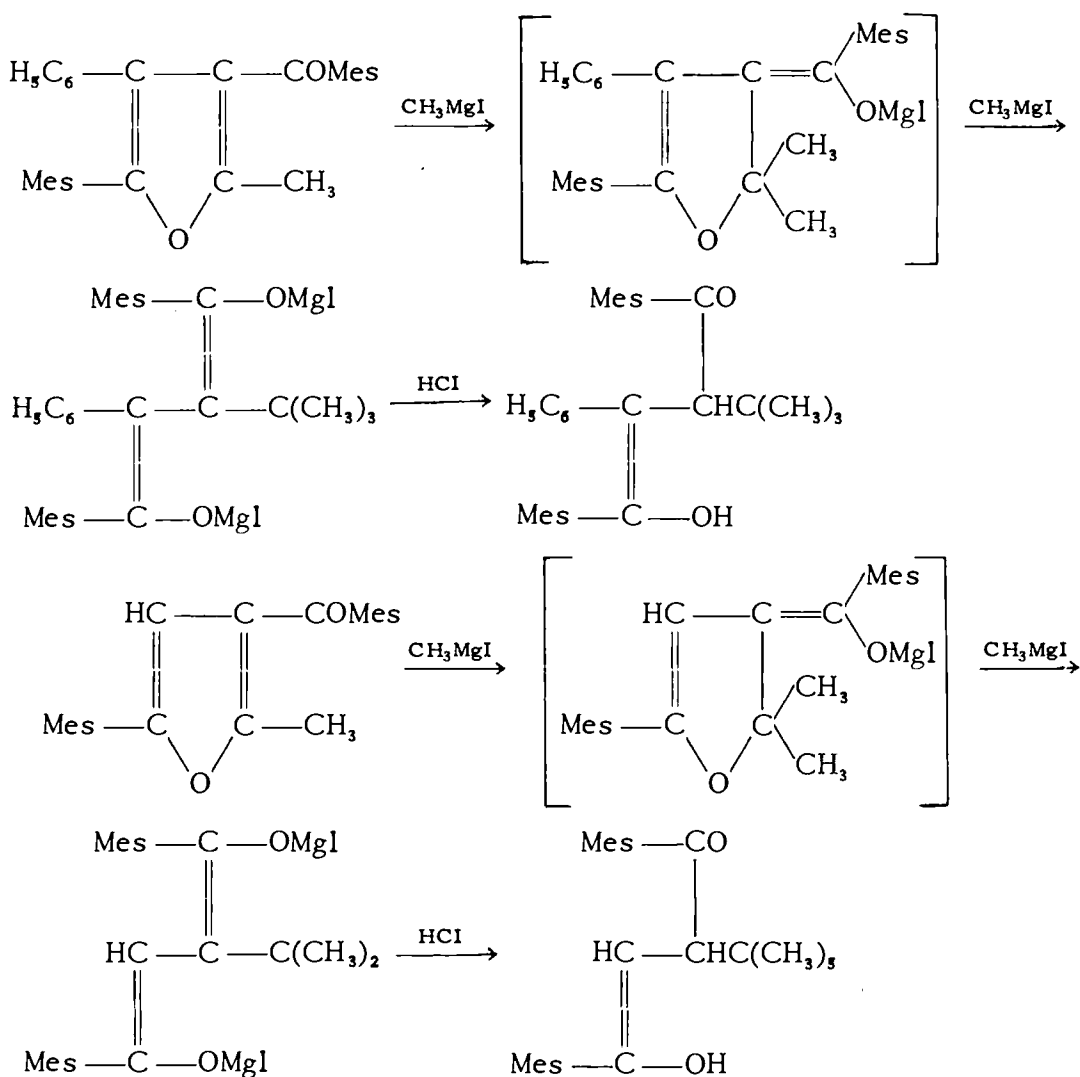


The general subject of organometallic reagent 1,4-addition to conjugated systems containing aromatic double bonds has been reviewed by Gaertner.^{211,1}

Cleavage reactions involving 1,4-addition. Various cleavage reactions which formally involve 1,4-addition have been reported. Among these are the amine cleavages studied by Benary.^{212,*}



Lutz and Reveley²¹³ report cleavages of furan rings, effected by treatment of 3-mesitylfurans with excess methylmagnesium iodide. They formulate the reactions as follows:



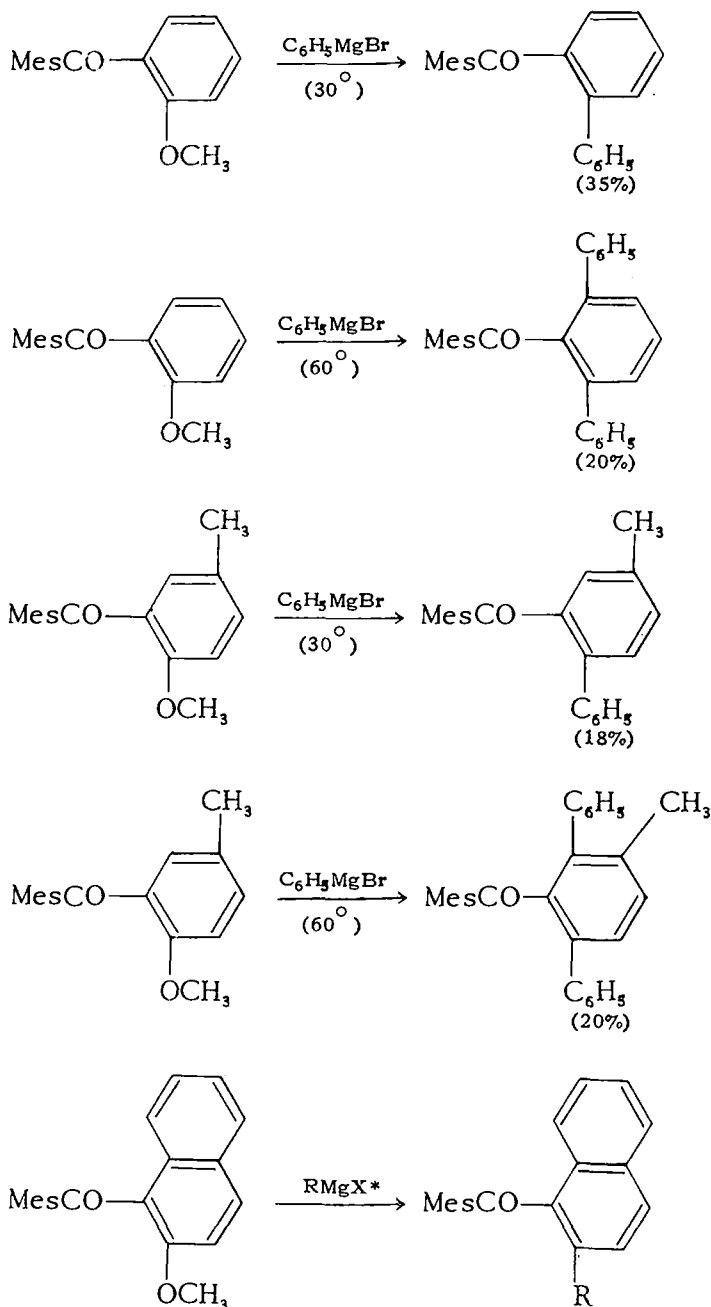
^{211,1}Gaertner, *Chem. Revs.*, 45, 493-521 (1949).

²¹²Benary, *Ber.*, 64B, 2543-5 (1931).

* R = *n*-C₃H₇, C₆H₅; R' = CH₃, C₂H₅; R'' = CH₃, C₂H₅, C₆H₅; X = Br, I.

²¹³Lutz and Reveley, *J. Am. Chem. Soc.*, 63, 3178-80, 3180-9 (1941).

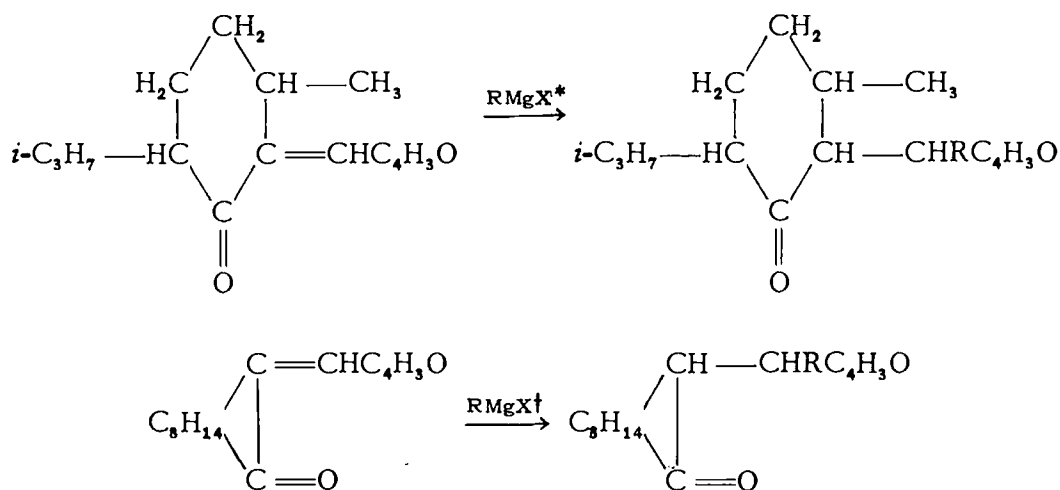
Aromatic ether cleavages that differ from those ordinarily observed (see Ether Cleavage by Grignard Reagents, Chapter XV), in that demethoxylation rather than demethylation occurs, are reported by Fuson *et al.*²¹⁴



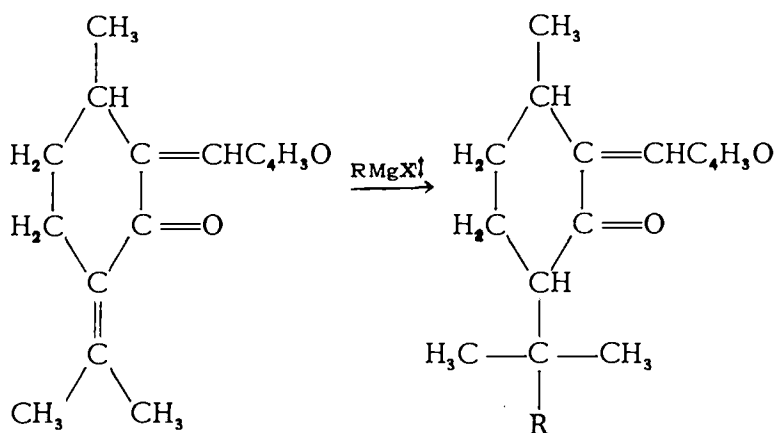
²¹⁴(a) Fuson and Speck, *J. Am. Chem. Soc.*, 64, 2446-8 (1942); (b) Fuson and Hornberger, *J. Org. Chem.*, 16, 631-6 (1951); (c) Fuson and Hornberger, *J. Org. Chem.*, 16, 637-42 (1951); (d) Fuson and Shealy, *J. Org. Chem.*, 16, 643-7 (1951).

* $\text{RMgX} = \text{CH}_3\text{MgI}$ (56%), $\text{C}_2\text{H}_5\text{MgBr}$ (80%), $n\text{-C}_4\text{H}_9\text{MgBr}$ (55%), $\text{C}_6\text{H}_5\text{MgBr}$ (59%), $1\text{-C}_{10}\text{H}_7\text{MgBr}$ (76%).

Instances of 1,4-addition involving an unsaturated *alpha* side-chain of a cyclic ketone are also known. Those of furfurylidene menthone and furfurylidene camphor, reported, respectively, by Boedtker *et al.*²¹⁵ and by Wolff,²¹⁶ are illustrative.



According to Maxim *et al.*²¹⁷ the 1,4-addition of Grignard reagents to 2-furfurylidene- and 2-benzylidenepulegone involves the isopropylidene double bond.



²¹⁵ Boedtker, Wiger, and Aagaard, *J. pharm. chim.*, 6, 193-204 (1927); *Chem. Abstr.*, 22, 584 (1928); *Chem. Zentr.*, 1927, II, 2189.

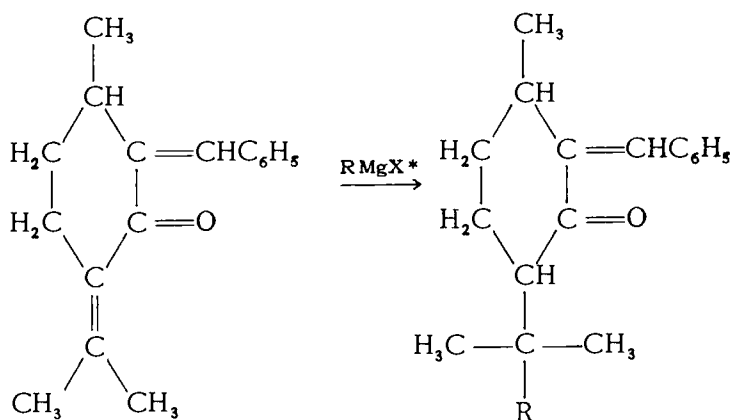
²¹⁶ Wolff, *Compt. rend.*, 172, 1357-60 (1921); *Chem. Zentr.*, 1921, III, 828; *Ann. chim.*, [9], 20, 82-130 (1923).

*R = CH₃, C₂H₅, n-C₃H₇, i-C₃H₇, n-C₄H₉, i-C₄H₉, i-C₅H₁₁, C₆H₅.

†R = C₆H₅, C₆H₅CH₂, 4-CH₃C₆H₄, 4-CH₃OC₆H₄.

²¹⁷ Maxim, Zugravesco, and Teodorescu, *Bull. soc. chim.*, [5], 7, 382-93 (1940); *Chem. Abstr.*, 36, 2851 (1942).

‡R = C₂H₅, n-C₃H₇, i-C₄H₉, C₆H₅, C₆H₅CH₂.



This was scarcely to be expected in view of the behavior of furfurylideneacetone, benzalacetone, and mesitylene oxide (see Table VI-XVI).

Other 1,4-additions involving unsaturated *alpha* side-chains of cyclic ketones have been reported by Doeuvre²¹⁸ (pulegone), Kohler²¹⁹ (2,6-dibenzylidene-3-methylcyclohexanone), and Haller and Bauer²²⁰ (α -benzylidenecamphor).

Both 1,2- and 1,4-additions, as well as mixtures of products, are reported for α,β -unsaturated single-ring cyclic ketones. On the basis of the available data no simple rules seem applicable to prediction of the order of addition.

Little is known concerning the behavior of compounds in which the carbon atoms *alpha* and *beta* to the carbonyl group are mutually triply bonded. Kohler (*loc. cit.*²⁰⁵) reported only 1,2-addition of phenylmagnesium bromide to phenylbenzoylacetylene. Fuson and Meek,²²¹ however, have found that the additions of methylmagnesium iodide, phenylmagnesium bromide, or mesitylmagnesium bromide to phenylmesitoylacetylene or mesitylmesitoylacetylene are predominantly, if not exclusively, 1,4.

1,6- (or "Transannular 1,4-") addition. Baeyer and Villiger²²² suggested, without proof of structure, that the addition of methylmagnesium iodide to fuchsone takes place in the 1,6 positions. This has since been confirmed by Julian and Gist,²²³ who also found that naphthofuchsone undergoes 1,6-addition, whereas anthrafuchsone (benzhydrylideneanthrone) reacts "normally" (*i.e.*, 1,2).

*R = C₂H₅, *n*-C₃H₇, *i*-C₄H₉, C₆H₅, C₆H₅CH₂.

²¹⁸Doeuvre, *Bull. soc. chim.*, [5], 6, 1067-9 (1939).

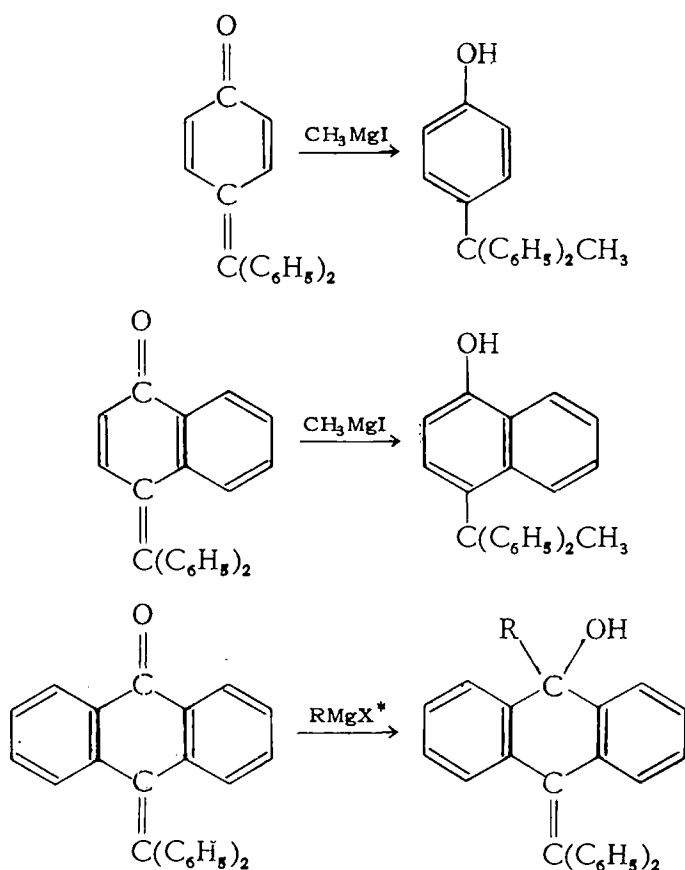
²¹⁹Kohler, *Am. Chem. J.*, 37, 369-92 (1907).

²²⁰Haller and Bauer, *Compt. rend.*, 142, 971-6 (1906); *Chem. Zentr.*, 1906, I, 1827.

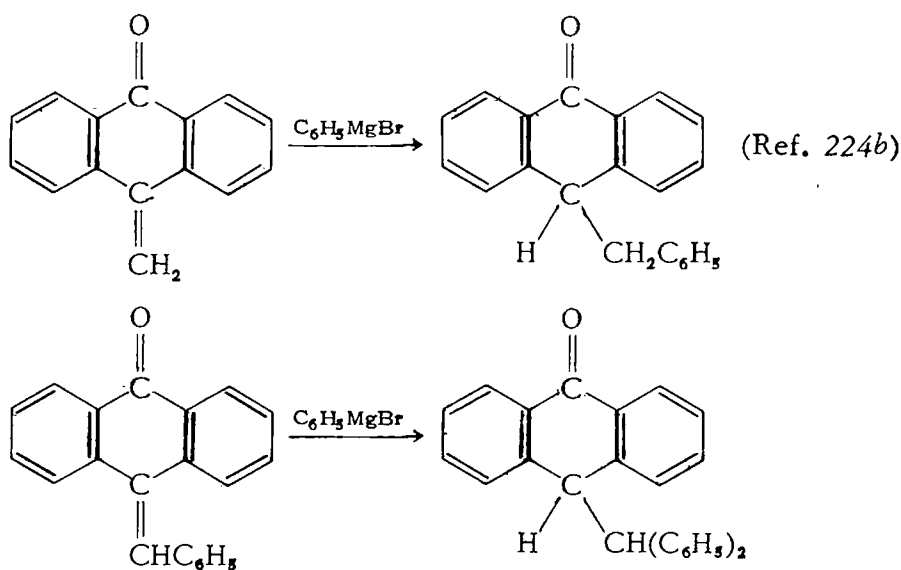
²²¹Fuson and Meek, *J. Org. Chem.*, 10, 551-61 (1945).

²²²Baeyer and Villiger, *Ber.*, 36, 2774-96 (1903).

²²³Julian and Gist, *J. Am. Chem. Soc.*, 57, 2030-2 (1934).



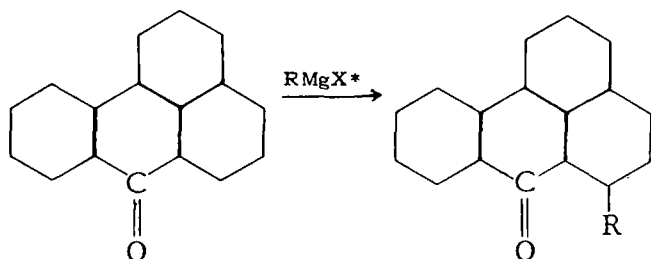
Methylene- and benzylideneanthrone, however, are reported to undergo 1,6-addition.²²⁴



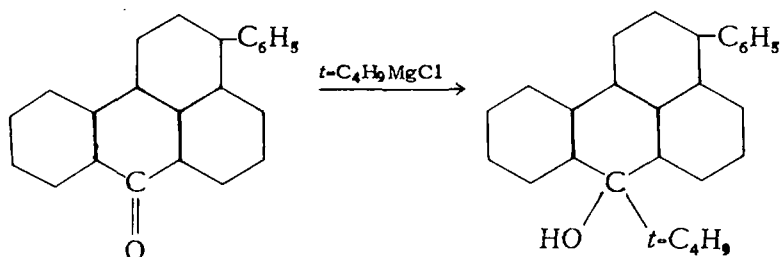
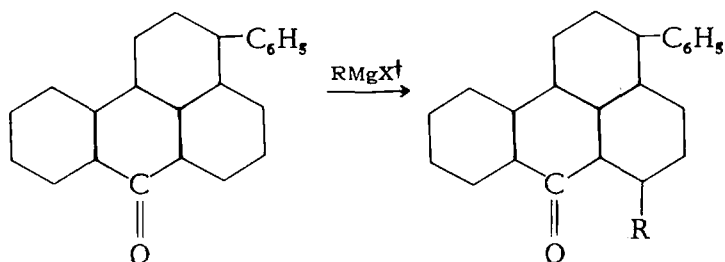
* $\text{RMgX} = \text{CH}_3\text{MgI}, \text{C}_6\text{H}_5\text{MgBr}$.

²²⁴(a) Julian and Magnani, *J. Am. Chem. Soc.*, 56, 2174-7 (1934); (b) Julian and Cole, *J. Am. Chem. Soc.*, 57, 1607-11 (1935).

The 1,6-additions of Grignard reagents to benzanthrone (7-benz[*de*]anthracen-7-one) claimed by Nakanishi²²⁵ and Clar²²⁶ have been rather thoroughly discredited by Charrier and Ghigi²²⁷ and by Allen and Overbaugh,²²⁸ who found 1,4-addition only.



3-Phenylbenzanthrone was found by Allen and Overbaugh²²⁹ to behave similarly with most Grignard reagents, but to undergo "normal" (*i.e.*, 1,2-) addition with *t*-butylmagnesium chloride.



1,6-Additions involving aromatic rings have, however, been observed by Fuson *et al.*^{230,†}

²²⁵Nakanishi, *Proc. Imp. Acad. Tokyo*, 9, 394-7 (1933); *Chem. Abstr.*, 28, 762 (1934).

²²⁶Clar, *Ber.*, 65B, 846-58 (1932).

²²⁷Charrier and Ghigi, *Gazz. chim. ital.*, 62, 928-36 (1932); *Chem. Abstr.*, 27, 1344 (1933); *Ber.*, 69B, 2211-32 (1936).

²²⁸Allen and Overbaugh, *J. Am. Chem. Soc.*, 57, 740-4 (1935).

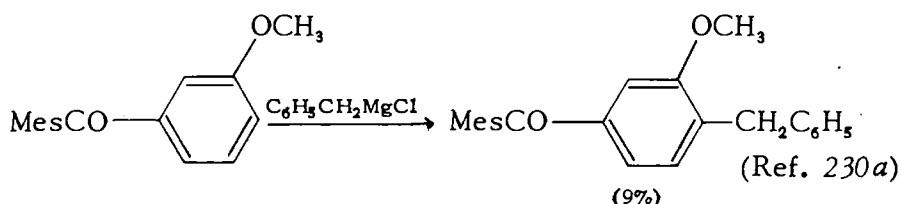
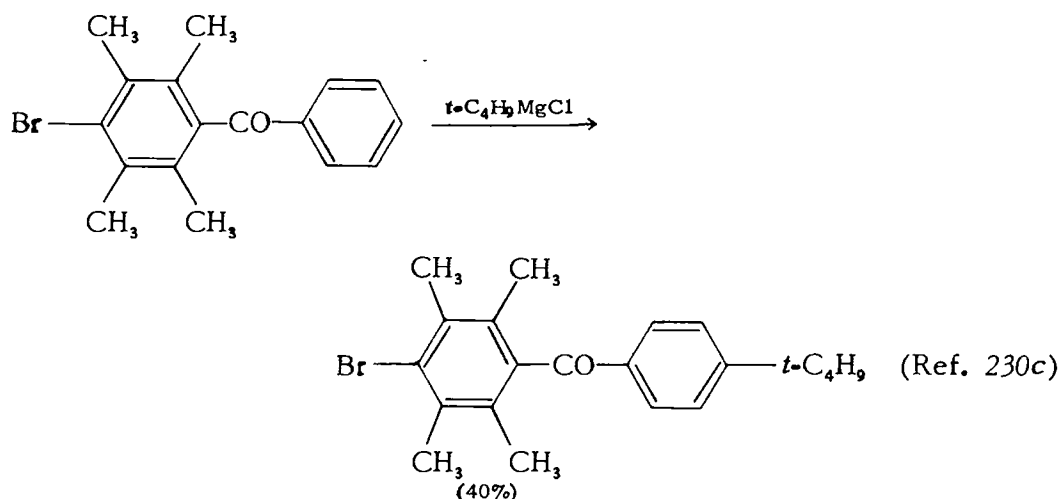
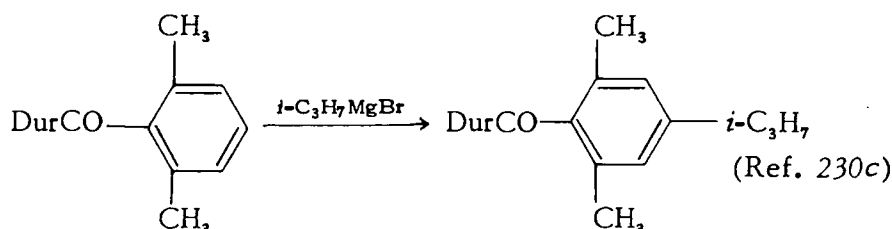
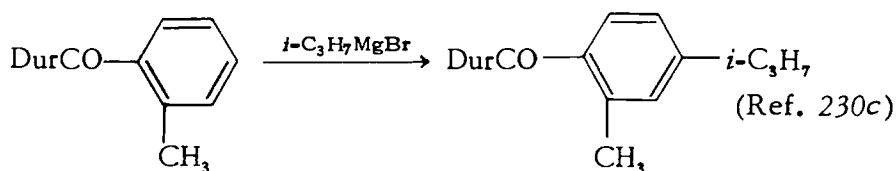
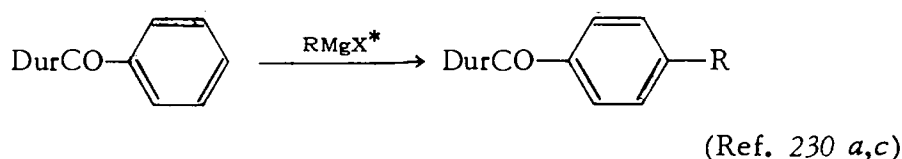
* $\text{RMgX} = \text{C}_2\text{H}_5\text{MgBr}$, $n\text{-C}_3\text{H}_7\text{MgI}$, $n\text{-C}_4\text{H}_9\text{MgI}$, $\text{C}_6\text{H}_5\text{MgBr}$, $(\text{CH}_2)_5\text{CHMgCl}$, $\text{C}_6\text{H}_5\text{CH}_2\text{MgCl}$, $n\text{-C}_7\text{H}_{13}\text{MgBr}$.

²²⁹Allen and Overbaugh, *J. Am. Chem. Soc.*, 57, 1322-5 (1935).

† $\text{R} = \text{C}_2\text{H}_5$, $n\text{-C}_4\text{H}_9$, $(\text{CH}_2)_5\text{CH}$, C_6H_5 , $\text{C}_6\text{H}_5\text{CH}_2$, $\text{C}_6\text{H}_5\text{CH}=\text{CH}$.

²³⁰(a) Fuson and McKusick, *J. Am. Chem. Soc.*, 65, 60-4 (1943); (b) Fuson and Gaertner, *J. Org. Chem.*, 13, 496-501 (1948); (c) Fuson and Tull, *J. Am. Chem. Soc.*, 71, 2542-6 (1949).

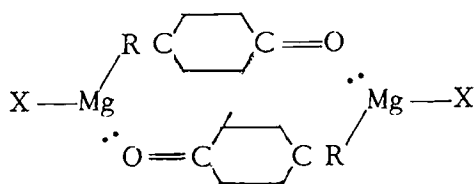
‡Dur = duryl = 2,3,5,6- $(\text{CH}_3)_4\text{C}_6\text{H}$ —; Mes = mesityl = 2,4,6- $(\text{CH}_3)_3\text{C}_6\text{H}_2$ —.



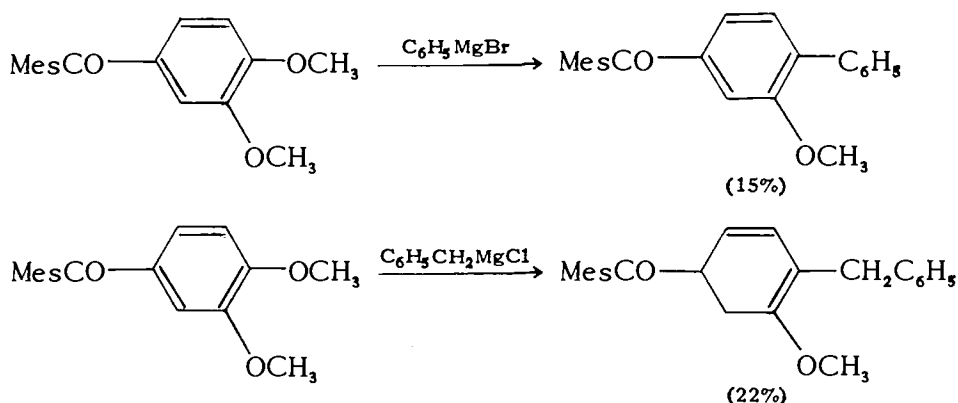
With regard to the 1,6-additions of Julian *et al.* (*loc. cit.*^{223, 224}), it is, perhaps, possible to conceive of a cycloid transition state (albeit somewhat strained) analogous to the quasi six-membered ring proposed to account for the 1,4-additions. With regard to those reported by Fuson *et al.* (*loc. cit.*²³⁰), however, the impediment to an extension of the 1,4-addition hypothesis appears more serious. In the latter case at least (and perhaps in both) it may be necessary to postulate a different mech-

*RMgX = *i*-C₃H₇MgBr (38%)^{230c}; *s*-C₄H₉MgBr (63%)^{230c}; *t*-C₄H₉MgCl (33%)^{230a}; (CH₂)₃CHMgCl (38%)^{230c}; C₆H₅CH₂MgCl (20%)^{230a}.

anism. A transition state involving two carbonyl complexes would seem a concept less far-fetched than one necessitating the constraint of a single complex into a monstrosly distorted cycloid.

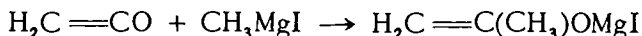


Cleavages involving 1,6-addition. 1,6-Displacements of methoxy groups analogous to the 1,4-displacements previously discussed have been reported by Fuson and Gaertner (*loc. cit.*^{230b}).



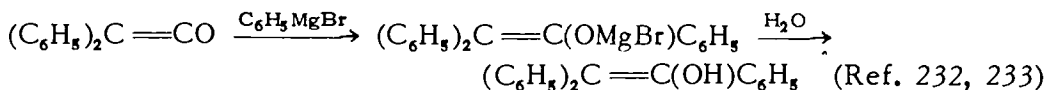
KETENES

Ketene itself, when treated with methylmagnesium iodide, is converted chiefly into resinous products, which is not altogether surprising in view of the fact that the primary product of Grignard reagent addition is the enolate of acetone (see Grignard Condensations of Aldehydes and Ketones, p. 176).



Traces of acetone may be detected in the reaction product.²³¹

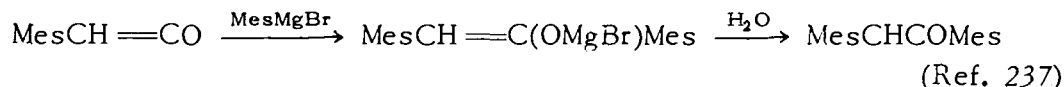
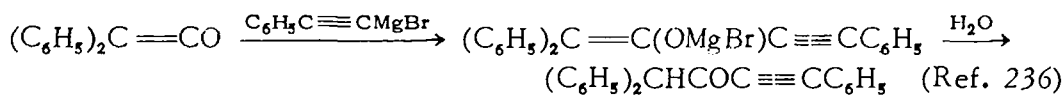
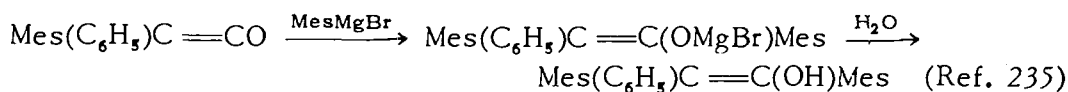
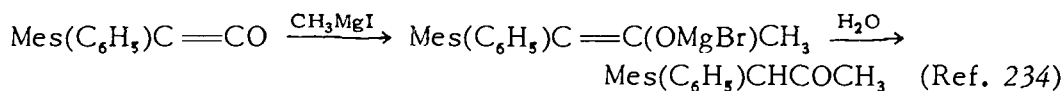
Aromatic ketenes react "normally" (*i.e.*, by 1,2-addition at the carbonyl double bond) with non-reducing Grignard reagents to form enolates, from which the enols, or corresponding ketones, are obtained by hydrolysis.



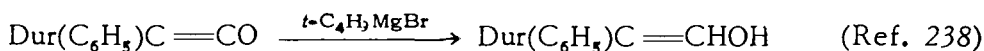
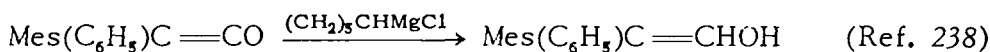
²³¹Deakin and Wilsmore, *J. Chem. Soc.*, 97, 1968-78 (1910).

²³²Staudinger, *Ann.*, 356, 51-123 (1907).

²³³Gilman and Heckert, *J. Am. Chem. Soc.*, 42, 1010-4 (1920).



Diaryl ketenes with at least one mesityl or duryl group are reduced by reducing Grignard reagents to the corresponding vinyl alcohols.



Other examples of the reactions of ketenes with Grignard reagents are to be found in Table VI-XVIII.

²³⁴Fuson, Armstrong, Chadwick, and Kneisley, *J. Am. Chem. Soc.*, 67, 386-93 (1946).

²³⁵Fuson, Armstrong, Kneisley, and Shenk, *J. Am. Chem. Soc.*, 66, 1464-6 (1944).

²³⁶Smith and Hoehn, *J. Am. Chem. Soc.*, 63, 1176-8 (1941).

²³⁷Fuson, Armstrong, and Shenk, *J. Am. Chem. Soc.*, 66, 964-7 (1944).

²³⁸Fuson, Foster, Shenk, and Maynert, *J. Am. Chem. Soc.*, 57, 1937-9 (1945).

TABLE VI-XVII
REACTIONS OF GRIGNARD REAGENTS WITH ALDEHYDES

Aldehyde	RMgX	Product(s)	Ref.
CH₂O			
HCHO	C ₂ H ₅ MgBr	<i>n</i> -C ₃ H ₇ OH (poor yield); CH ₂ (OC ₂ H ₅) ₂	372
HCHO (from 50 g. paraform)	H ₂ C=CHC≡CMgBr (65 g. C ₄ H ₄)	H ₂ C=CHC≡CCH ₂ OH (65%)	245
HCHO	2-Furyl-MgI	Furfuryl alcohol (31%)	109
HCHO	Pyrryl-MgX	A pyrrolic ether, C ₂₂ H ₁₄ O ₂ N ₂ ; tar and other unidentified products	236
HCHO	Butenyl-MgBr*	H ₂ C=CHCH(CH ₃)CH ₂ OH (<i>ca.</i> 50%); octadienes; no CH ₃ CH=CHCH ₂ CH ₂ OH	283
HCHO (from 38 g. paraform)	<i>s</i> -C ₄ H ₉ MgBr (150 g. C ₄ H ₉ Br)	<i>s</i> -C ₄ H ₉ CH ₂ OH (64.5 g., 67%)	363
HCHO	<i>t</i> -C ₄ H ₉ MgCl	<i>t</i> -C ₄ H ₉ CH ₂ OH (42-50%)	55
HCHO (from 7.5 g. paraform)	3-Furfuryl-MgCl (14.3 g. C ₅ H ₅ ClO)	3-Methyl-2-furfuryl alcohol (4.6 g., 33.4%)	451
HCHO (from 50 g. paraform)	2-Thenyl-MgCl (0.242 mole)	2-Methyl-3-thenyl alcohol (15.1 g., 49%)	443
HCHO (<i>ca.</i> 1 equiv.)	<i>n</i> -C ₃ H ₇ C≡CMgBr (2 moles)	<i>n</i> -C ₃ H ₇ C≡CCH ₂ OH (140 g., 71%)	450
HCHO (from 45 g. paraform)	(CH ₂) ₄ CHMgBr (149 g. C ₅ H ₉ Br)	(CH ₂) ₄ CHCH ₂ OH (62-64%)	251
HCHO (from 80 g., 2.67 moles paraform)	(+)-CH ₃ (C ₂ H ₅)CHCH ₂ MgCl† (207 g., 1.93 mole C ₅ H ₁₁ Cl)	(+)-CH ₃ (C ₂ H ₅)CHCH ₂ CH ₂ OH (101.9 g., 52%)	388
HCHO (from 65 g. paraform)	CH ₃ (<i>n</i> -C ₃ H ₇)CHMgBr (302 g. C ₅ H ₁₁ Br)	CH ₃ (<i>n</i> -C ₃ H ₇)CHCH ₂ OH (108 g., 53%)	363
HCHO	<i>t</i> -C ₅ H ₁₁ MgCl	<i>t</i> -C ₅ H ₁₁ CH ₂ OH (40-47%)	55
HCHO (from 50.0 g. paraform)	CH ₃ OCH ₂ CH(CH ₃)CH ₂ MgCl (122.5 g., 1.0 mole C ₅ H ₁₁ ClO)	CH ₃ OCH ₂ CH(CH ₃)CH ₂ CH ₂ OH (79.0 g., 67%)	425
HCHO	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ CH ₂ OH (61%)	373
HCHO (from 1.5-2.0 equiv. "trioxymethylene")	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ OH (70%)	372

* From 80% CH₃CH=CHCH₂Br, 20% H₂C=CHCHBrCH₃.

† From (+)-1-chloro-2-methylbutane, [α]_D²⁰ + 1.26.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CH₂O (<i>cont.</i>)			
HCHO (<i>ca.</i> 1 equiv.)	<i>n</i> -C ₄ H ₉ C≡CMgBr (82 g. C ₆ H ₁₀)	<i>n</i> -C ₄ H ₉ C≡CCH ₂ OH (92 g., 82%)	450,19
HCHO	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CHCH ₂ OH (64-69%)	108,265
HCHO	(CH ₂) ₅ CHMgBr	(CH ₂) ₅ CHCH ₂ OH (61-65%)	3,426
HCHO	CH ₃ (<i>i</i> -C ₄ H ₉)CHMgBr	<i>i</i> -C ₄ H ₉ CH(CH ₃)CH ₂ OH (30%)	47
HCHO	3-F ₃ CC ₆ H ₄ MgBr	3-F ₃ CC ₆ H ₄ CH ₂ OH (38%)	427
HCHO (20 g., 0.66 mole)	C ₆ H ₅ CH ₂ MgCl (0.85 mole)	2-CH ₃ C ₆ H ₄ CH ₂ OH (35 g., 40%)	454
HCHO	(CH ₂) ₅ CHCH ₂ MgBr	(CH ₂) ₅ CHCH ₂ CH ₂ OH (46%)	111
HCHO	CH ₃ (<i>n</i> -C ₃ H ₇)CH(CH ₂) ₂ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)CH(CH ₂) ₃ OH	204
HCHO	(C ₂ H ₅) ₃ CMgCl	(C ₂ H ₅) ₃ CCH ₂ OH (10%)	351,352
HCHO	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₃ H ₇)CMgCl	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₃ H ₇)CCH ₂ OH (30%)	351
HCHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	(C ₂ H ₅) ₂ N(CH ₂) ₃ CH ₂ OH	233
HCHO	C ₆ H ₅ C≡CMgBr (12 g. C ₈ H ₆)	C ₆ H ₅ C≡CCH ₂ OH (4 g.)	389
HCHO	Indolyl-MgX	β-Indolylmethanol; β-indolylmethyl ether	236
HCHO	<i>n</i> -C ₆ H ₁₃ C≡CMgBr	<i>n</i> -C ₆ H ₁₃ C≡CCH ₂ OH (83%)	389
HCHO	(CH ₂) ₅ CHCH ₂ CH ₂ MgBr	(CH ₂) ₅ CH(CH ₂) ₃ OH (79%)	426
HCHO	3,3-Dimethylcyclohexyl-MgBr (143.3 g. C ₈ H ₁₅ Br)	3,3-Dimethylcyclohexylmethanol (71.0 g., 67%)	374
HCHO	<i>n</i> -C ₅ H ₁₁ (CH ₃) ₂ CMgCl	<i>n</i> -C ₅ H ₁₁ (CH ₃) ₂ CCH ₂ OH (40.7%)	351
HCHO	CH ₃ (<i>n</i> -C ₃ H ₇)CH(CH ₂) ₃ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)CH(CH ₂) ₄ OH (58%)	46
HCHO	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₄ H ₉)CMgCl	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₄ H ₉)CCH ₂ OH (31%)	351
HCHO (from 10 g. paraform)	2-Thianaphthenylmethyl-MgCl (0.0167 mole)	2-Methyl-3-thianaphthenylmethanol (1.05 g., 35%)	444
HCHO (from 40 g. paraform)	3-Thianaphthenylmethyl-MgCl (45 g. C ₉ H ₇ ClS)	2-(3-Thianaphthenyl)ethanol; 2-Methyl-3-thianaphthenylmethanol (1.3 g., 18%); 2-(2-hydroxymethyl-3-thianaphthenyl)ethanol (?)	445

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
CH₂O (<i>cont.</i>)			
HCHO	2-Methylindolyl-MgX	α -Methyl- β -indolylmethanol	236
HCHO	C ₆ H ₅ (CH ₂) ₃ MgBr	C ₆ H ₅ (CH ₂) ₄ OH	34
HCHO	CH ₃ COC(C ₂ H ₅) ₃ + C ₂ H ₅ MgBr	(C ₂ H ₅) ₃ CCOCH ₂ CH ₂ OH* (34%)	354
HCHO (from 25 g. "trioxymethylene")	1-C ₁₀ H ₇ MgBr (64 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ CH ₂ OH (58%)	372
HCHO	(CH ₂) ₅ CH(CH ₂) ₄ MgBr	(CH ₂) ₅ CH(CH ₂) ₅ OH (58%)	426
HCHO	1-C ₁₀ H ₇ CH ₂ MgCl	(1-C ₁₀ H ₇ CH ₂ -) ₂ (6.4%); 1-CH ₃ -2- HOCH ₂ C ₁₀ H ₆ ; unidentified product	110
HCHO	1-C ₁₀ H ₇ CH ₂ MgCl (18 g. C ₁₁ H ₉ Cl)	1-C ₁₀ H ₇ CH ₂ CH ₂ OH (8 g.)	448
HCHO	2-C ₁₀ H ₇ CH ₂ MgCl	2-C ₁₀ H ₇ CH ₂ CH ₂ OH	448
HCHO	2-C ₁₀ H ₇ CH ₂ MgBr	2-C ₁₀ H ₇ CH ₂ CH ₂ OH; 1-HOCH ₂ - 2-CH ₃ C ₁₀ H ₆ (?)	305
HCHO	4-CH ₃ C ₁₀ H ₆ -1-MgBr	1-HOCH ₂ -4-CH ₃ C ₁₀ H ₆ (40-50%)	373
HCHO (from 123 g. paraform)	6-CH ₃ OC ₁₀ H ₆ -1-MgI (555 g. C ₁₁ H ₉ IO)	1-HOCH ₂ -6-CH ₃ OC ₁₀ H ₆ (300 g., 80%)	29
HCHO	C ₂ H ₅ (C ₆ H ₅)CH(CH ₂) ₂ MgBr	C ₂ H ₅ (C ₆ H ₅)CH(CH ₂) ₃ OH	203
HCHO	L-C ₂ H ₅ (C ₆ H ₅)CH(CH ₂) ₂ MgBr	L-C ₂ H ₅ (C ₆ H ₅)CH(CH ₂) ₃ OH	203
HCHO	(CH ₃) ₅ C ₆ MgBr	(CH ₃) ₅ C ₆ CH ₂ OH	51
HCHO	9-Phenanthryl-MgBr	9-Phenanthrylmethanol (50%)	11
HCHO	<i>n</i> -C ₁₆ H ₃₃ MgBr	<i>n</i> -C ₁₇ H ₃₅ OH (53%)	347
HCHO	<i>n</i> -C ₁₇ H ₃₅ MgBr	<i>n</i> -C ₁₈ H ₃₇ OH (64%)	347
HCHO (excess)	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)MgBr (5.00 g. C ₂₀ H ₁₅ Br)	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)CH ₂ OH (2.05 g.)	182
(CH₂O)_x			
"Trioxymethylene"	(≡CMgBr) ₂	(≡CCH ₂ OH) ₂	81,154
"Trioxymethylene"	HC≡CMgBr	HC≡CCH ₂ OH	154

*Enolate addition.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
$(\text{CH}_2\text{O})_x$ (cont.)			
"Trioxymethylene" (30 g.)	$\text{H}_2\text{C}=\text{CHCH}_2\text{Br}$ (121 g.) + Mg (24 g.)	$\text{H}_2\text{C}=\text{CHCH}_2\text{CH}_2\text{OH}$ (26%)	166,258; c/. 261
"Trioxymethylene"	$\text{H}_2\text{C}=\text{CHC}\equiv\text{CMgBr}$	No reaction	244
Paraformaldehyde (10 g.)	Butenyl-MgBr (62 g. $\text{C}_4\text{H}_7\text{Br}$)	$\text{H}_2\text{C}=\text{CHCH}(\text{CH}_3)\text{CH}_2\text{OH}$ (15 g., 38%)	439
"Trioxymethylene"	$n\text{-C}_4\text{H}_9\text{MgCl}$	$n\text{-C}_5\text{H}_{11}\text{OH}$ (64%)	386
"Trioxymethylene"	$n\text{-C}_4\text{H}_9\text{MgBr}$	$n\text{-C}_5\text{H}_{11}\text{OH}$ (70%); $(n\text{-C}_5\text{H}_{11}\text{O})_2\text{CH}_2$	34
"Trioxymethylene"	$n\text{-C}_4\text{H}_9\text{MgBr}$	$n\text{-C}_5\text{H}_{11}\text{OH}$ (47%)	254
"Trioxymethylene"	$i\text{-C}_4\text{H}_9\text{MgBr}$	$i\text{-C}_5\text{H}_{11}\text{OH}$ (50%)	321
"Trioxymethylene"	$s\text{-C}_4\text{H}_9\text{MgBr}$	$\text{CH}_3(\text{C}_2\text{H}_5)\text{CHCH}_2\text{OH}$ (59%)	254
"Trioxymethylene"	$t\text{-C}_4\text{H}_9\text{MgCl}$	$t\text{-C}_4\text{H}_9\text{CH}_2\text{OH}$	59
"Polyoxymethylene" (1.2-1.3 excess)	$t\text{-C}_4\text{H}_9\text{MgCl}$	$t\text{-C}_4\text{H}_9\text{CH}_2\text{OH}$ (40%)	336
"Trioxymethylene" (42 g.)	$(\text{CH}_2)_4\text{CHMgCl}$ (94 g. $\text{C}_5\text{H}_9\text{Cl}$)	$(\text{CH}_2)_4\text{CHCH}_2\text{OH}$ (40 g., 40%); [$(\text{CH}_2)_4\text{CH}-$] $_2$ (ca. 8 g., 12.5%); [$(\text{CH}_2)_4\text{CHO}$] $_2\text{CH}_2$ (45 g., 40.5%)	328,371
"Polyoxymethylene"	$n\text{-C}_5\text{H}_{11}\text{MgBr}$	$n\text{-C}_6\text{H}_{13}\text{OH}$ (47%)	336
"Trioxymethylene"	$\text{CH}_3(n\text{-C}_3\text{H}_7)\text{CHMgBr}$	$\text{CH}_3(n\text{-C}_3\text{H}_7)\text{CHCH}_2\text{OH}$ (70%)	254
"Trioxymethylene" (60 g.)	$\text{C}_6\text{H}_5\text{MgBr}$ (157 g. $\text{C}_6\text{H}_5\text{Br}$)	$\text{C}_6\text{H}_5\text{CH}_2\text{Br}$ (35 g.); $(\text{C}_6\text{H}_5-)_2$ (10 g.); $\text{C}_6\text{H}_5\text{CHO}$ (20 g. bisulfite comp'd.)	219
"Trioxymethylene"	$(\text{CH}_2)_5\text{CHMgCl}$	$(\text{CH}_2)_5\text{CHCH}_2\text{OH}$	288
Paraformaldehyde (100 g.)	$(\text{CH}_2)_5\text{CHMgBr}$ (163 g. $\text{C}_6\text{H}_{11}\text{Br}$)	$(\text{CH}_2)_5\text{CHCH}_2\text{OH}$ (70 g., 60%)	221
"Trioxymethylene"	$\text{CH}_3(i\text{-C}_4\text{H}_9)\text{CHMgBr}$	$\text{CH}_3(i\text{-C}_4\text{H}_9)\text{CHCH}_2\text{OH}$ (ca. 8%); "sec- ondary products" (chiefly)	327
"Trioxymethylene" (23 g.)	1-Cyclohexenylmethyl-MgCl (20 g. $\text{C}_7\text{H}_{11}\text{Cl}$)	$\text{C}_6\text{H}_9\text{CH}_2\text{CH}_2\text{OH}$ (40%)	448
"Trioxymethylene" (18 g.)	$(\text{CH}_2)_5\text{CHCH}_2\text{MgI}$ (134 g. $\text{C}_7\text{H}_{13}\text{I}$)	$(\text{CH}_2)_5\text{CHCH}_2\text{CH}_2\text{OH}$ (30 g.)	371
"Trioxymethylene"	$(\text{CH}_2)_6\text{CHMgI}$	$(\text{CH}_2)_6\text{CHCH}_2\text{OH}$	284
"Trioxymethylene"	Indolyl-MgX	β -Indolylmethanol	236

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
$(\text{CH}_2\text{O})_x$ (cont.)			
"Trioxymethylene" (24 g.)	2- $\text{CH}_3\text{C}_6\text{H}_4\text{CH}_2\text{MgBr}$ (40 g. $\text{C}_6\text{H}_9\text{Br}$)	2- $\text{CH}_3\text{C}_6\text{H}_4\text{CH}_2\text{CH}_2\text{OH}$ (1.5%); 2,3- (CH_3) ₂ $\text{C}_6\text{H}_3\text{CH}_2\text{OH}$ (28.5%)	448
"Trioxymethylene" (20 g.)	3- $\text{CH}_3\text{C}_6\text{H}_4\text{CH}_2\text{MgBr}$ (185 g. $\text{C}_6\text{H}_9\text{Br}$)	3- $\text{CH}_3\text{C}_6\text{H}_4\text{CH}_2\text{CH}_2\text{OH}$ (8-10 g.)	441
"Trioxymethylene"	4- $\text{CH}_3\text{C}_6\text{H}_4\text{CH}_2\text{MgBr}$	4- $\text{CH}_3\text{C}_6\text{H}_4\text{CH}_2\text{CH}_2\text{OH}$ (7.5%); 2,5-(CH_3) ₂ $\text{C}_6\text{H}_3\text{CH}_2\text{OH}$ (22.5%)	448
"Trioxymethylene"	$\text{CH}_3(\text{C}_6\text{H}_5)\text{CHMgBr}$	$\text{CH}_3(\text{C}_6\text{H}_5)\text{CHCH}_2\text{OH}$	448
"Trioxymethylene"	(CH_3) ₂ $\text{C}=\text{CH}(\text{CH}_2)_2\text{CH}(\text{CH}_3)\text{MgBr}$	(CH_3) ₂ $\text{C}=\text{CH}(\text{CH}_2)_2\text{CH}(\text{CH}_3)\text{CH}_2\text{OH}$ (15%)	76
"Trioxymethylene"	1-Indenyl-MgBr	α -Benzofulvanol	122
"Trioxymethylene"	2-Methylindolyl-MgX	α -Methyl- β -indolylmethanol; α -Methyl- β -indolylmethyl ether	236
"Trioxymethylene"	$\text{C}_6\text{H}_5(\text{CH}_2)_3\text{MgBr}$	$\text{C}_6\text{H}_5(\text{CH}_2)_4\text{OH}$ (54-59%); n - $\text{C}_3\text{H}_7\text{C}_6\text{H}_5$; [$\text{C}_6\text{H}_5(\text{CH}_2)_3-$] ₂	344
"Trioxymethylene"	3,5-(CH_3) ₂ $\text{C}_6\text{H}_3\text{CH}_2\text{MgBr}$	2,4,6-(CH_3) ₃ $\text{C}_6\text{H}_2\text{CH}_2\text{OH}$; [2,4,6-(CH_3) ₃ $\text{C}_6\text{H}_2\text{CH}_2$] ₂ O	442
"Trioxymethylene" (30 g.)	2,4,6-(CH_3) ₃ $\text{C}_6\text{H}_2\text{MgBr}$ (250 g. $\text{C}_9\text{H}_{11}\text{Br}$)	2,4,6-(CH_3) ₃ $\text{C}_6\text{H}_2\text{CH}_2\text{OH}$ (4 g.)	442
"Trioxymethylene"	(CH_3) ₂ $\text{C}=\text{CH}(\text{CH}_2)_2\text{CH}(\text{CH}_3)\text{CH}_2\text{MgBr}$	(CH_3) ₂ $\text{C}=\text{CH}(\text{CH}_2)_2\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_2\text{OH}$ (41%)	76
"Trioxymethylene"	4- i - $\text{C}_3\text{H}_7\text{C}_6\text{H}_4\text{CH}_2\text{MgCl}$	4- i - $\text{C}_3\text{H}_7\text{C}_6\text{H}_4\text{CH}_2\text{CH}_2\text{OH}$ (31%)	27
"Trioxymethylene"	$\text{C}_6\text{H}_5\text{O}(\text{CH}_2)_5\text{MgI}$	$\text{C}_6\text{H}_5\text{O}(\text{CH}_2)_5\text{CH}_2\text{OH}$	345
"Trioxymethylene" (35 g.)	n - $\text{C}_{12}\text{H}_{25}\text{MgCl}$ (120 g. $\text{C}_{12}\text{H}_{25}\text{Cl}$)	n - $\text{C}_{13}\text{H}_{27}\text{OH}$ (70 g., 60%); (n - $\text{C}_{13}\text{H}_{27}\text{O}$) ₂ CH_2 (15 g., 14%); $\text{C}_{24}\text{H}_{50}$; olefins (16 g.)	328
"Trioxymethylene"	(C_6H_5) ₂ $\text{C}=\text{CHMgBr} + \text{Mg}$	(C_6H_5) ₂ $\text{C}=\text{CHCH}_2\text{OH}$ (21%); [(C_6H_5) ₂ $\text{C}=\text{CH}-$] ₂	373
Paraformaldehyde (2.84 g., 0.094 mole)	n - $\text{C}_{14}\text{H}_{29}\text{MgBr}$ (15.5 g., 0.057 mole $\text{C}_{14}\text{H}_{29}\text{Br}$)	n - $\text{C}_{15}\text{H}_{31}\text{OH}$ (2.2 g., 17.2%)	62

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
$(\text{CH}_2\text{O})_x$ (cont.)			
"Trioxymethylene" (30 g.)	$n\text{-C}_{18}\text{H}_{37}\text{MgCl}$ (144 g. $\text{C}_{18}\text{H}_{37}\text{Cl}$)	$\text{C}_{18}\text{H}_{36} + \text{C}_{18}\text{H}_{38}$ (20 g., 16%); $n\text{-C}_{19}\text{H}_{39}\text{OH}$ (84 g., 59%); $(n\text{-C}_{19}\text{H}_{39}\text{O})_2\text{CH}_2$ (28 g., 22%)	328
C_2HOBr_3			
Br_3CCHO	$(\equiv \text{CMgI})_2$	$[\equiv \text{CCH}(\text{OH})\text{CBr}_3]_2$	155
C_2HOCl_3			
CCl_3CHO	CH_3MgBr	$\text{CCl}_3(\text{CH}_3)\text{CHOH}$ (40%); $\text{CCl}_3\text{CH}_2\text{OH}$; tar	172,405
CCl_3CHO	CH_3MgI	$\text{CCl}_3(\text{CH}_3)\text{CHOH}$ (40%)	385,132,362, 379,405
CCl_3CHO	$(\equiv \text{CMgBr})_2$	$[\equiv \text{CCH}(\text{OH})\text{CCl}_3]_2$	149,81,419
CCl_3CHO	$\text{C}_2\text{H}_5\text{MgBr}$	$\text{CCl}_3(\text{C}_2\text{H}_5)\text{CHOH}$ (10-15%); $\text{CCl}_3\text{CH}_2\text{OH}$ (50-60%)	153
CCl_3CHO (37 g.)	$\text{C}_2\text{H}_5\text{MgBr}$ (32 g. $\text{C}_2\text{H}_5\text{Br}$)	$\text{CCl}_3(\text{C}_2\text{H}_5)\text{CHOH}$ (13-14 g.)	142
CCl_3CHO	$\text{C}_2\text{H}_5\text{MgBr}$	$\text{CCl}_3\text{CH}_2\text{OH}$ (54%); tar*	107
CCl_3CHO	$\text{C}_2\text{H}_5\text{MgI}$	$\text{CCl}_3(\text{C}_2\text{H}_5)\text{CHOH}$ (16%)	379
CCl_3CHO	$\text{H}_2\text{C}=\text{CHCH}_2\text{Cl} + \text{Mg}$	$\text{CCl}_3(\text{H}_2\text{C}=\text{CHCH}_2)\text{CHOH}$	390
CCl_3CHO (37 g.)	$n\text{-C}_3\text{H}_7\text{MgBr}$ (34 g. $\text{C}_3\text{H}_7\text{Br}$)	$\text{CCl}_3(n\text{-C}_3\text{H}_7)\text{CHOH}$ (10-11 g.)	142
CCl_3CHO (74 g.)	$i\text{-C}_3\text{H}_7\text{MgBr}$ (68 g. $\text{C}_3\text{H}_7\text{Br}$)	$\text{CCl}_3(i\text{-C}_3\text{H}_7)\text{CHOH}$ (30-32 g.)	142
CCl_3CHO (0.25 mole)	2-Thienyl-MgBr (0.25 mole $\text{C}_4\text{H}_3\text{BrS}$)	$\text{CCl}_3(\alpha\text{-C}_4\text{H}_3\text{S})\text{CHOH}$ (36 g., 62%)	97
CCl_3CHO (74 g.)	$n\text{-C}_4\text{H}_9\text{MgBr}$ (70 g. $\text{C}_4\text{H}_9\text{Br}$)	$\text{CCl}_3(n\text{-C}_4\text{H}_9)\text{CHOH}$ (35-37 g.)	143
CCl_3CHO (0.25 mole)	$n\text{-C}_5\text{H}_{11}\text{MgBr}$ (0.25 mole $\text{C}_5\text{H}_{11}\text{Br}$)	$\text{CCl}_3\text{CH}_2\text{OH}$ (19-23%); C_5H_{10} (23-27 g. $\text{C}_5\text{H}_{10}\text{Br}_2$)†	95

* In a total of seventeen runs, including experiments in which $\text{C}_2\text{H}_5\text{MgCl}$ and $\text{C}_2\text{H}_5\text{MgI}$ were used, and employing temperatures varying from -75° to 34° and reaction times of fifteen minutes to twenty-four hours, no significant deviations from the results above recorded were observed.

† "Normal" or "inverse" addition.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C_2HOCl_3 (cont.)			
CCl_3CHO	$4-BrC_6H_4MgBr$	$CCl_3(4-BrC_6H_4)CHOH$ (29%)	379, 152
CCl_3CHO	C_6H_5MgBr	$CCl_3(C_6H_5)CHOH$	379
CCl_3CHO	C_6H_5MgX	$CCl_3(C_6H_5)CHOH$ (ca. 70%)	94
CCl_3CHO	$HBrC=CH(CH_2)_2C\equiv CMgBr$	$CCl_3[HBrC=CH(CH_2)_2C\equiv C]CHOH$ (90%)	151
CCl_3CHO (0.2 mole)	$(CH_2)_5CHMgBr$ (0.2 mole $C_6H_{11}Br$)	CCl_3CH_2OH (12.5 g.); C_6H_{10} (14.5 g. $C_6H_{10}Br_2$); $[(CH_2)_5CH-]_2$ (1 g.)*	94, 379
CCl_3CHO (0.25 mole)	$n-C_6H_{13}MgBr$ (0.25 mole $C_6H_{13}Br$)	CCl_3CH_2OH (21.0–22.5 g.); C_6H_{12} (27.0–28.0 g. $C_6H_{12}Br_2$); tar (4.2–4.5 g.)†	95
CCl_3CHO (0.25 mole)	$n-C_6H_{13}MgBr$ (0.25 mole $C_6H_{13}Br$)	CCl_3CH_2OH (26.0 g.); C_6H_{12} (33.5 g. $C_6H_{12}Br_2$); tar (2.0 g.)†	95
CCl_3CHO (37 g.)	$C_6H_5CH_2MgCl$ (35 g. C_7H_7Cl)	$CCl_3(C_6H_5CH_2)CHOH$ (10–11 g.)	142
CCl_3CHO	$C_6H_5CH_2MgCl$	$CCl_3(C_6H_5CH_2)CHOH$ (26%); CCl_3CH_2OH (1.06%); § tar	107, 379
CCl_3CHO	$2-CH_3C_6H_4MgX$	$CCl_3(2-CH_3C_6H_4)CHOH$ (ca. 70%)	94
CCl_3CHO	$2-CH_3C_6H_4MgBr$	$CCl_3(2-CH_3C_6H_4)CHOH$ (80%)	417
CCl_3CHO	$4-CH_3C_6H_4MgBr$	$CCl_3(4-CH_3C_6H_4)CHOH$ (50%)	417
CCl_3CHO	$C_6H_5C\equiv CMgBr$	$Cl_3C(C_6H_5C\equiv C)CHOH$ (75%)	148
CCl_3CHO (0.25 mole)	$C_6H_5(CH_2)_2MgBr$ (0.25 mole C_8H_9Br)	CCl_3CH_2OH (12–16 g.); $C_6H_5CH=CH_2$ (6 g.); $[C_6H_5(CH_2)_2-]_2$ (1–2 g.)	64
CCl_3CHO	$2,5-(CH_3)_2C_6H_3MgBr$	$CCl_3[2,5-(CH_3)_2C_6H_3]CHOH$ (53%)	297
CCl_3CHO (0.25 mole)	$C_6H_5(CH_2)_3MgBr$ (0.25 mole $C_9H_{11}Br$)	CCl_3CH_2OH (13–18 g.); $C_6H_5CH_2CH=CH_2$ (12 g.); $[C_6H_5(CH_2)_3-]_2$ (3–7 g.)	64

* "Normal" addition; the same products were obtained in somewhat higher yields when "inverse" addition was employed.

† "Normal" addition.

‡ "Inverse" addition.

§ Probably attributable to atmospheric oxygen contamination of the Grignard reagent (see *textual* discussion of alkoxide reduction p. 158).

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₂HOCl₃ (<i>cont.</i>)			
CCl ₃ CHO (0.25 mole)	C ₆ H ₅ (CH ₂) ₄ MgBr (0.25 mole C ₁₀ H ₁₃ Br)	CCl ₃ CH ₂ OH (16-18 g.); C ₆ H ₅ (CH ₂) ₂ CH=CH ₂ (29-34 g. as bromide); [C ₆ H ₅ (CH ₂) ₄ -] ₂ (3 g.)	64
C₂HOF₃			
CF ₃ CHO (0.2-0.3 mole)	CH ₃ MgI (0.4-0.6 mole)	CF ₃ (CH ₃)CHOH (67.0%)	436
CF ₃ CHO (0.2-0.3 mole)	C ₂ H ₅ MgI (0.4-0.6 mole)	CF ₃ (C ₂ H ₅)CHOH (60.0%); CF ₃ CH ₂ OH (20.0%)	436
CF ₃ CHO (0.2-0.3 mole)	<i>i</i> -C ₃ H ₇ MgBr (0.4-0.6 mole)	CF ₃ CH ₂ OH (87.0%)	436
CF ₃ CHO (0.2-0.3 mole)	<i>t</i> -C ₄ H ₉ MgCl (0.4-0.6 mole)	CF ₃ (<i>t</i> -C ₄ H ₉)CHOH (7.0%); CF ₃ CH ₂ OH (84.0%)	436
CF ₃ CHO (0.2-0.3 mole)	C ₆ H ₅ MgBr (0.4-0.6 mole)	CF ₃ (C ₆ H ₅)CHOH (88.0%)	436
CF ₃ CHO (0.2-0.3 mole)	C ₆ H ₅ CH ₂ MgBr (0.4-0.6 mole)	CF ₃ (C ₆ H ₅ CH ₂)CHOH (81.0%)	436
C₂H₂OCl₂			
CHCl ₂ CHO	CH ₃ MgBr	CHCl ₂ (CH ₃)CHOH (57.4%)	362
C₂H₃OCl			
ClCH ₂ CHO	(≡CMgBr) ₂	ClCH ₂ (HC≡C)CHOH	391
ClCH ₂ CHO	H ₂ C=CHCH ₂ MgBr	ClCH ₂ (H ₂ C=CHCH ₂)CHOH (40%)	26
ClCH ₂ CHO (40 g.)	4-BrC ₆ H ₄ MgBr (118 g. C ₆ H ₄ Br ₂)	ClCH ₂ (4-BrC ₆ H ₄)CHOH (40%)	26
C₂H₄O			
CH ₃ CHO	CH ₃ MgI	(CH ₃) ₂ CHOH (67%)	121
CH ₃ CHO	(≡CMgBr) ₂	[≡CCH(CH ₃)OH] ₂ (<70%)	370,150,418
CH ₃ CHO	(≡CMgBr) ₂	CH ₃ (HC≡C)CHOH (20-23%)	392
CH ₃ CHO (0.25 mole) + (C ₆ H ₅) ₂ CO (0.50 mole)	(≡CMgBr) ₂	CH ₃ CH(OH)C≡CC(C ₆ H ₅) ₂ OH (17 g., 27%); [≡CC(C ₆ H ₅) ₂ OH] (61 g.)	294

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O (cont.)			
CH ₃ CHO (44 g.)	C ₂ H ₅ MgBr (115 g. C ₂ H ₅ Br)	CH ₃ (C ₂ H ₅)CHOH (80%)	49
CH ₃ CHO (from 300 g. paraldehyde)	C ₂ H ₅ MgBr (680 g. C ₂ H ₅ Br)	CH ₃ (C ₂ H ₅)CHOH (275 g., 67%)	363,375
CH ₃ CHO	HC≡CCH ₂ MgBr	CH ₃ (HC≡CCH ₂)CHOH (50%)	449
CH ₃ CHO	H ₂ C=CHCH ₂ MgCl	CH ₃ (H ₂ C=CHCH ₂)CHOH (57%)	424
CH ₃ CHO	H ₂ C=CHCH ₂ MgBr	CH ₃ (H ₂ C=CHCH ₂)CHOH (with 2 equiv. CH ₃ CHO, 40%; 1.5 equiv. CH ₃ CHO, 44-45%; 1.2 equiv. CH ₃ CHO, 49.5%)	258
CH ₃ CHO	H ₂ C=CHCH ₂ Br + Mg	CH ₃ (H ₂ C=CHCH ₂)CHOH (12-20%)	262
CH ₃ CHO	H ₂ C=CHCH ₂ Br + Mg	CH ₃ (H ₂ C=CHCH ₂)CHOH (55%)	311
CH ₃ CHO	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)CHOH (50%)	169,341,375
CH ₃ CHO (from 300 g. paraldehyde)	<i>n</i> -C ₃ H ₇ MgBr (from 768 g. bromide)	CH ₃ (<i>n</i> -C ₃ H ₇)CHOH (76%)*	363
CH ₃ CHO	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (53-54%)	80,255
CH ₃ CHO	H ₂ C=CHC≡CMgBr	CH ₃ (H ₂ C=CHC≡C)CHOH (57%)	244
CH ₃ CHO	Pyrryl-MgBr	1,1-Di-2-pyrrylethane; 1-(2-pyrryl)-1-(2-pyrrilidene)ethane	256
CH ₃ CHO	H ₂ C=C(CH ₃)CH ₂ MgCl	CH ₃ [H ₂ C=C(CH ₃)CH ₂]CHOH (65%)	312
CH ₃ CHO (50 g.)	H ₂ C=C(CH ₃)CH ₂ Cl (90 g.) + Mg (24 g.)	CH ₃ [H ₂ C=C(CH ₃)CH ₂]CHOH (ca. 20 g. crude)	171
CH ₃ CHO	Butenyl-MgBr†	CH ₃ [H ₂ C=CHCH(CH ₃)]CHOH (<25%)	258
CH ₃ CHO	Butenyl-MgBr‡	CH ₃ [H ₂ C=CHCH(CH ₃)]CHOH (ca. 84%); octadienes. [No CH ₃ (CH ₃ CH=CHCH ₂)CHOH]	283
CH ₃ CHO (100 g.)	(CH ₃) ₂ C=CHMgBr (195 g. C ₄ H ₇ Br)	CH ₃ [(CH ₃) ₂ C=CH]CHOH (20 g.); (CH ₃) ₂ C=CH ₂ ; C ₂ H ₅ OH	189

* Aldehyde vapor led into Grignard reagent solution in stream of nitrogen.

† From crotyl bromide (CH₃CH=CHCH₂Br).‡ From 80% CH₃CH=CHCH₂Br, 20% H₂C=CHCHBrCH₃.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O (cont.)			
CH ₃ CHO	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (54%)	333,58,254, 341
CH ₃ CHO	<i>n</i> -C ₄ H ₉ MgI	CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (<i>ca.</i> 10%)	375
CH ₃ CHO	<i>i</i> -C ₄ H ₉ MgCl	CH ₃ (<i>i</i> -C ₄ H ₉)CHOH	114
CH ₃ CHO	<i>i</i> -C ₄ H ₉ MgBr	CH ₃ (<i>i</i> -C ₄ H ₉)CHOH (49%)	47,327,375
CH ₃ CHO	(CH ₃) ₃ SiCH ₂ MgCl	CH ₃ [(CH ₃) ₃ SiCH ₂]CHOH	357
CH ₃ CHO (33 g.)	H ₂ C=C(CH ₃)C≡CMgBr (from 84 g. C ₂ H ₅ Br)	CH ₃ [H ₂ C=C(CH ₃)C≡C]CHOH (56 g.)	244
CH ₃ CHO	(CH ₃) ₂ C=C(CH ₃)MgBr	CH ₃ [(CH ₃) ₂ C=C(CH ₃)]CHOH	191
CH ₃ CHO	(CH ₂) ₄ CHMgCl	CH ₃ [(CH ₂) ₄ CH]CHOH (33%)	429,85
CH ₃ CHO	(CH ₂) ₄ CHMgBr	CH ₃ [(CH ₂) ₄ CH]CHOH	428
CH ₃ CHQ	<i>n</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>n</i> -C ₅ H ₁₁)CHOH	135
CH ₃ CHO	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>i</i> -C ₅ H ₁₁)CHOH (60-85%)*	326
CH ₃ CHO	CH ₃ (C ₂ H ₅)CHCH ₂ MgBr	CH ₃ [CH ₃ (C ₂ H ₅)CHCH ₂]CHOH	63
CH ₃ CHO	<i>t</i> -C ₅ H ₁₁ MgCl	CH ₃ (<i>t</i> -C ₅ H ₁₁)CHOH (36%)	84
CH ₃ CHO	<i>t</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>t</i> -C ₅ H ₁₁)CHOH	355
CH ₃ CHO	4-BrC ₆ H ₄ MgBr	CH ₃ (4-BrC ₆ H ₄)CHOH (75%)	277,152
CH ₃ CHO (80 g., 1.365 mole)	3-ClC ₆ H ₄ MgBr (229 g., 1.2 mole C ₆ H ₄ BrCl)	CH ₃ (3-ClC ₆ H ₄)CHOH (154.5-164.5 g., 82.5-88.0%)	259
CH ₃ CHO (56.5 g.)	4-FC ₆ H ₄ MgBr (209.8 g. C ₆ H ₄ BrF)	CH ₃ (4-FC ₆ H ₄)CHOH (110.5 g., 66%)	15
CH ₃ CHO	C ₆ H ₅ MgBr	CH ₃ (C ₆ H ₅)CHOH (<93%)	105
CH ₃ CHO (45 g.)	C ₆ H ₅ MgBr (75 g. C ₆ H ₅ Br)	CH ₃ COC ₆ H ₅ (<i>ca.</i> 60x%); CH ₃ (C ₆ H ₅)CHBr	446,447
CH ₃ CHO	C ₆ H ₅ MgBr	CH ₃ (C ₆ H ₅)CHOH (optically active, 1.33°; after 24 hrs., 0.33°)†	28

* Tuot (326) reports the yields for a series of carbinol preparations as varying from 60-85%.

† Grignard reagent prepared in *N,N*-dimethylbornylamine; condensed with aldehyde in benzene.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O (<i>cont.</i>)			
CH ₃ CHO	C ₆ H ₅ MgBr	C ₆ H ₅ CH(CH ₃)OH (60–88%); (optically inactive)*	313
CH ₃ CHO	(CH ₂) ₅ CHMgCl	CH ₃ [(CH ₂) ₅ CH]CHOH ("yield excellent")	35
CH ₃ CHO	(CH ₂) ₅ CHMgBr	CH ₃ [(CH ₂) ₅ CH]CHOH	385,440
CH ₃ CHO	2-Br-4-F ₃ CC ₆ H ₃ MgBr	CH ₃ (2-Br-4-F ₃ CC ₆ H ₃)CHOH	15
CH ₃ CHO (9.5 g.)	3-F ₃ C-4-FC ₆ H ₃ MgBr (42.0 g. C ₇ H ₃ BrF ₄)	CH ₃ (3-F ₃ C-4-FC ₆ H ₃)CHOH (22.0 g., 61%)	15
CH ₃ CHO	3-F ₃ CC ₆ H ₄ MgBr	CH ₃ (3-F ₃ CC ₆ H ₄)CHOH (83%)	259
CH ₃ CHO	C ₆ H ₅ CH ₂ MgCl	CH ₃ (C ₆ H ₅ CH ₂)CHOH (65.6%)	356,305,195
CH ₃ CHO (<i>ca.</i> 0.3 mole)	C ₆ H ₅ CH ₂ MgCl (<i>ca.</i> 0.4 mole)	CH ₃ (C ₆ H ₅ CH ₂)CHOH (32%); 2-CH ₃ CH(OH)C ₆ H ₄ CH ₂ CH(OH)CH ₃ (29%)	454
CH ₃ CHO	3-CH ₃ C ₆ H ₄ MgBr	CH ₃ (3-CH ₃ C ₆ H ₄)CHOH (71%)	259
CH ₃ CHO	4-CH ₃ C ₆ H ₄ MgBr	CH ₃ (4-CH ₃ C ₆ H ₄)CHOH	205
CH ₃ CHO	<i>n</i> -C ₅ H ₁₁ C≡CMgBr (25 g. <i>n</i> -C ₅ H ₁₁ C≡CH)	CH ₃ (<i>n</i> -C ₅ H ₁₁ C≡C)CHOH (12 g., crude)	237
CH ₃ CHO	(C ₂ H ₅ O) ₂ CHC≡CMgBr	CH ₃ [(C ₂ H ₅ O) ₂ CHC≡C]CHOH	115,423
CH ₃ CHO	(CH ₂) ₅ CHCH ₂ MgI	CH ₃ [(CH ₂) ₅ CHCH ₂]CHOH (40%)	101
CH ₃ CHO	2-Methylcyclohexyl-MgBr	1-Methyl-2-ethylidenecyclohexane	241
CH ₃ CHO	<i>n</i> -C ₇ H ₁₅ MgBr	CH ₃ (<i>n</i> -C ₇ H ₁₅)CHOH (80–85%)	332
CH ₃ CHO	<i>n</i> -C ₇ H ₁₅ MgI	CH ₃ (<i>n</i> -C ₇ H ₁₅)CHOH ("very little")	375
CH ₃ CHO	CH ₃ (<i>n</i> -C ₅ H ₁₁)CHMgBr	CH ₃ [CH ₃ (<i>n</i> -C ₅ H ₁₁)CH]CHOH (60%)	2
CH ₃ CHO (20 g.)	C ₆ H ₅ C≡CMgBr (22 g. C ₆ H ₅ ≡CH)	CH ₃ (C ₆ H ₅ C≡C)CHOH (15 g.); recovered C ₆ H ₅ C≡CH (7 g.)	237,44,279
CH ₃ CHO	2-ClC ₆ H ₄ CH(CO ₂ MgCl)MgCl †	CH ₃ [2-ClC ₆ H ₄ CH(CO ₂ H)]CHOH (69%)	158

* Grignard reagent prepared in (+)-2-methoxybutane.

† In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135–54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₂H₄O (cont.)			
CH ₃ CHO	C ₆ H ₅ OC≡CMgBr	CH ₃ (C ₆ H ₅ OC≡C)CHOH (28%; 64%, crude); C ₆ H ₅ OH* (9%)	160
CH ₃ CHO [†]	Indolyl-MgBr	[CH ₃ (β-C ₈ H ₆ N)CH] ₂ O	256
CH ₃ CHO	Indolyl-MgBr	1,1-Bis-β-indolyethane	376
CH ₃ CHO	C ₆ H ₅ (CH ₂) ₂ MgBr	CH ₃ (C ₆ H ₅ CH ₂ CH ₂)CHOH (85%)	39,31
CH ₃ CHO	3-CH ₃ C ₆ H ₄ CH ₂ MgBr	CH ₃ (3-CH ₃ C ₆ H ₄ CH ₂)CHOH	441
CH ₃ CHO	(CH ₂) ₅ CHC≡CMgBr	CH ₃ [(CH ₂) ₅ CHC≡C]CHOH	116
CH ₃ CHO (excess)	C ₆ H ₅ (CH ₂) ₃ MgBr	CH ₃ [C ₆ H ₅ (CH ₂) ₃]CHOH (75%)	438
CH ₃ CHO (19.8 g.)	(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)MgBr (86 g. C ₈ H ₁₅ Br)	CH ₃ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)]CHOH (30 g.); (CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)COCH ₃ (10 g.); C ₈ H ₁₆ + C ₈ H ₁₄ (5 g.); high-boiling residue (7 g.)	77
CH ₃ CHO (220 g.)	<i>n</i> -C ₈ H ₁₇ MgBr (970 g. C ₈ H ₁₇ Br)	CH ₃ (<i>n</i> -C ₈ H ₁₇)CHOH (634 g., 80%)	274
CH ₃ CHO	<i>n</i> -C ₈ H ₁₇ MgI	CH ₃ (<i>n</i> -C ₈ H ₁₇)CHOH ('very little')	375
CH ₃ CHO	CH ₃ (<i>n</i> -C ₆ H ₁₃)CHMgBr	CH ₃ [CH ₃ (<i>n</i> -C ₆ H ₁₃)CH]CHOH	117
CH ₃ CHO	1-Indenyl-MgBr	Methyl-1-indenylmethanol (71%)	60
CH ₃ CHO [†]	2-Methylindolyl-MgBr	[CH ₃ (C ₉ H ₆ N)CH] ₂ O	256
CH ₃ CHO	2-Methylindolyl-MgBr	1,1-Bis-(α-methyl-β-indolyl)ethane	376
CH ₃ CHO	C ₆ H ₅ CH=CHCH ₂ MgCl	CH ₃ [H ₂ C=CHCH(C ₆ H ₅)]CHOH; (C ₆ H ₅ CH=CHCH ₂ -) ₂ ; C ₆ H ₅ CH=CHCH ₃	258
CH ₃ CHO (75 g., 1.7 mole)	3- <i>s</i> -C ₄ H ₉ C ₆ H ₄ MgBr (321 g., 7.505 mole C ₁₀ H ₁₃ Br)	CH ₃ (3- <i>s</i> -C ₄ H ₉ C ₆ H ₄)CHOH (150 g., 0.843 mole, 56%)	220
CH ₃ O	3- <i>t</i> -C ₄ H ₉ C ₆ H ₄ MgBr	CH ₃ (3- <i>t</i> -C ₄ H ₉ C ₆ H ₄)CHOH (56%)	259

* Attributed to cleavage of the C₆H₅OC≡C⁻ ion.[†]Paraldehyde reacts similarly but is less reactive.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O (<i>cont.</i>)			
CH ₃ CHO	(CH ₃) ₅ C ₆ MgBr	CH ₃ [(CH ₃) ₅ C ₆]CHOH (5%)	51,52
CH ₃ CHO	(CH ₃) ₅ C ₆ Br + CH ₃ I + Mg	(CH ₃) ₆ C ₆ (small am't); (CH ₃) ₅ C ₆ H (small am't); (CH ₃) ₅ C ₆ CHO (?) (20%)	296
CH ₃ CHO (120 g., 2.73 moles)	4-(CH ₂) ₅ CHC ₆ H ₄ MgBr (574 g., 2.4 moles C ₁₂ H ₁₅ Br)	CH ₃ [4-(CH ₂) ₅ CHC ₆ H ₄]CHOH (80 g., 18%); [4-(CH ₂) ₅ CHC ₆ H ₄ —] ₂ (20 g., 2.6%); "polymeric residue"	220
CH ₃ CHO (0.2 mole)	4-(C ₂ H ₅) ₃ SiC ₆ H ₄ MgBr (0.1 mole C ₁₂ H ₁₉ BrSi)	CH ₃ [4-(C ₂ H ₅) ₃ SiC ₆ H ₄]CHOH ("satisfactory yield")	125
CH ₃ CHO	9-Phenanthryl-MgBr	Methyl-9-phenanthrylmethanol (75%)	11
CH ₃ CHO	(C ₆ H ₅) ₂ C=CHMgBr	CH ₃ [(C ₆ H ₅) ₂ C=CH]CHOH	373
CH ₃ CHO (20 ml.)	C ₁₆ H ₃₃ MgBr* (41 g., 0.135 mole C ₁₆ H ₃₃ Br)	6,10,14-Trimethylpentadecanol (25.5 g., 70%)	303
CH ₃ CHO	(C ₆ H ₅) ₃ CMgCl	"Passive"	299
CH ₃ CHO (0.077 mole)	3-Cholesteryl-MgCl (9.2 g., 0.023 mole C ₂₇ H ₄₅ Cl)	"Methyl-3-cholesterylcarbinol"	18
(C₂H₄O)_x			
Paraldehyde	C ₂ H ₅ I + Mg	CH ₃ (C ₂ H ₅)CHOH	416
Paraldehyde	C ₆ H ₅ MgBr	DL-CH ₃ (C ₆ H ₅)CHOH [†] (60%)	313
C₃HOFF₅			
C ₂ F ₅ CHO (0.2-0.3 mole)	CH ₃ MgI (0.4-0.6 mole)	CH ₃ (C ₂ F ₅)CHOH (87.0%)	436
C ₂ F ₅ CHO (0.2-0.3 mole)	C ₂ H ₅ MgI (0.4-0.6 mole)	C ₂ F ₅ (C ₂ H ₅)CHOH (33.6%); C ₂ F ₅ CH ₂ OH (55.5%)	436
C ₂ F ₅ CHO : MgBr ₂ (0.2-0.3 mole)	C ₂ H ₅ MgI (0.4-0.6 mole)	C ₂ F ₅ (C ₂ H ₅)CHOH (58.0%); C ₂ F ₅ CH ₂ OH (36.4%)	436

* *i*-C₆H₁₃CH(CH₃)(CH₂)₃CH(CH₃)(CH₂)₃MgBr.[†] Grignard reagent prepared in *N,N*-dimethylbornylamine; paraldehyde added; one hour at 110-120°.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₃HOF₅ (cont.)			
C ₂ F ₅ CHO (0.2-0.3 mole)	<i>i</i> -C ₃ H ₇ MgBr (0.4-0.6 mole)	C ₂ F ₅ CH ₂ OH (90.0%)	436
C ₂ F ₅ CHO (0.2-0.3 mole)	<i>t</i> -C ₄ H ₉ MgCl (0.4-0.6 mole)	C ₂ F ₅ (<i>t</i> -C ₄ H ₉)CHOH (14.3%)	436
		C ₂ F ₅ CH ₂ OH (76.2%)	
C ₂ F ₅ CHO (0.2-0.3 mole)	C ₆ H ₅ MgBr (0.4-0.6 mole)	C ₂ F ₅ (C ₆ H ₅)CHOH (86.0%)	436
C ₂ F ₅ CHO (0.2-0.3 mole)	C ₆ H ₅ CH ₂ MgCl (0.4-0.6 mole)	C ₂ F ₅ (C ₆ H ₅ CH ₂)CHOH (83.0%)	436
C₃H₃OBr			
H ₂ C=CHBr	CH ₃ MgI	CH ₃ (H ₂ C=CHBr)CHOH ("good yield")	199
H ₂ C=CHBr	(≡CMgBr) ₂	HC≡C(H ₂ C=CHBr)CHOH	391
C₃H₃OBr₃			
BrCH ₂ CBr ₂ CHO	(≡CMgBr) ₂	HC≡C(H ₂ C=CHBr)CHOH	391
C₃H₄O			
H ₂ C=CHCHO (+ hydroquinone)	CH ₃ MgBr	CH ₃ (H ₂ C=CH)CHOH (52%)*	20,272
H ₂ C=CHCHO (112 g.)	CH ₃ MgBr (200 g. CH ₃ Br)	CH ₃ (H ₂ C=CH)CHOH (73%)	48
H ₂ C=CHCHO	CH ₃ MgBr	CH ₃ (H ₂ C=CH)CHOH (80% on basis of acrolein; 64% on basis of Mg; 58% on basis of bromide)	258
H ₂ C=CHCHO (+ 1 g. hydroquinone per mole)	CH ₃ MgX [†]	CH ₃ (H ₂ C=CH)CHOH (52%)*	20,68,72,361
H ₂ C=CHCHO (110 g.) (+ hydroquinone)	CH ₃ MgI (284 g. CH ₃ I)	CH ₃ (H ₂ C=CH)CHOH (52%)	334,66,198,361
H ₂ C=CHCHO	(≡CMgBr) ₂	[≡CCH(OH)CH=CH ₂] ₂	81,420

* Without hydroquinone stabilization the yield of alcohol was *ca.* 25%.[†] X = Br, I.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₃H₄O (cont.)			
H ₂ C=CHCHO	(≡CMgBr) ₂	HC≡C(H ₂ C=CH)CHOH	391
H ₂ C=CHCHO (25 g.)	(≡CMgBr) ₂ (50 g. Mg)	HC≡C(H ₂ C=CH)CHOH (11 g.); [≡CCH(OH)CH=CH ₂] ₂ (ca. 2 g.)	393
H ₂ C=CHCHO (28 g.)	(≡CMgBr) ₂ (12 g. Mg)	[≡CCH(OH)CH=CH ₂] ₂ (10 g.); (H ₂ C=CHCHO) _x (15 g.)	394
H ₂ C=CHCHO (100 g.)	C ₂ H ₅ MgBr (80 g. Mg)	H ₂ C=CH(C ₂ H ₅)CHOH (122 g.); colored residue (20 g.)	185
H ₂ C=CHCHO	C ₂ H ₅ MgBr	H ₂ C=CH(C ₂ H ₅)CHOH (65%)	272,33
H ₂ C=CHCHO (1.00 mole)	C ₂ H ₅ MgBr (1.85 mole)	H ₂ C=CH(C ₂ H ₅)CHOH (57.4%)*	70,67,72
H ₂ C=CHCHO	H ₂ C=CHCH ₂ MgBr	H ₂ C=CH ₂ (CH ₂ =CHCH ₂)CHOH (35-40%)	258
H ₂ C=CHCHO	<i>n</i> -C ₃ H ₇ MgBr	H ₂ C=CH(<i>n</i> -C ₃ H ₇)CHOH (60%)	272,33,249
H ₂ C=CHCHO	<i>n</i> -C ₃ H ₇ MgBr	H ₂ C=CH(<i>n</i> -C ₃ H ₇)CHOH (41%)	68,72
H ₂ C=CHCHO	<i>i</i> -C ₃ H ₇ MgBr	H ₂ C=CH(<i>i</i> -C ₃ H ₇)CHOH (15%)	33
H ₂ C=CHCHO	Butenyl-MgBr †	H ₂ C=CH[H ₂ C=CHCH(CH ₃)]CHOH (<25%)	258
H ₂ C=CHCHO	<i>n</i> -C ₄ H ₉ MgBr	H ₂ C=CH(<i>n</i> -C ₄ H ₉)CHOH (45%)	272,33
H ₂ C=CHCHO	<i>n</i> -C ₄ H ₉ MgBr	H ₂ C=CH(<i>n</i> -C ₄ H ₉)CHOH (35%)	68,72
H ₂ C=CHCHO	<i>i</i> -C ₄ H ₉ MgBr	H ₂ C=CH(<i>i</i> -C ₄ H ₉)CHOH	33
H ₂ C=CHCHO (56.0 g., 1 mole)	CH ₃ O(CH ₂) ₃ MgCl (108.6 g. C ₄ H ₉ ClO)	H ₂ C=CH[CH ₃ O(CH ₂) ₃]CHOH (60.0 g., 46%)	409
H ₂ C=CHCHO	<i>n</i> -C ₅ H ₁₁ MgBr	H ₂ C=CH(<i>n</i> -C ₅ H ₁₁)CHOH (46%)	118
H ₂ C=CHCHO	<i>i</i> -C ₅ H ₁₁ MgBr	H ₂ C=CH(<i>i</i> -C ₅ H ₁₁)CHOH (59%)	72
H ₂ C=CHCHO (40 g.)	C ₆ H ₅ MgBr	H ₂ C=CH(C ₆ H ₅)CHOH (50 g.)	179,41,69, 185,238
H ₂ C=CHCHO	<i>n</i> -C ₆ H ₁₃ MgBr	H ₂ C=CH(<i>n</i> -C ₆ H ₁₃)CHOH (94%)	72

* Maximum yield; smaller excess of Grignard reagent or excess of aldehyde gave lower yields.

† From crotyl bromide (CH₃CH=CHCH₂Br); see Chapter XVII, Allylic Rearrangements in Grignard Reactions.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₃H₄O (<i>cont.</i>)			
H ₂ C=CHCHO	C ₆ H ₅ CH ₂ MgX*	H ₂ C=CH(C ₆ H ₅ CH ₂)CHOH (<i>ca.</i> 5%)	69; <i>cf.</i> 61
H ₂ C=CHCHO	2-CH ₃ C ₆ H ₄ MgBr	H ₂ C=CH(2-CH ₃ C ₆ H ₄)CHOH (55%)	69
H ₂ C=CHCHO (14 g.)	4-CH ₃ C ₆ H ₄ MgBr (43 g. C ₇ H ₇ Br)	H ₂ C=CH(4-CH ₃ C ₆ H ₄)CHOH (20 g.); (4-CH ₃ C ₆ H ₄ -) ₂	41
H ₂ C=CHCHO	4-CH ₃ C ₆ H ₄ MgBr	H ₂ C=CH(4-CH ₃ C ₆ H ₄)CHOH (57%)	69
H ₂ C=CHCHO	(C ₂ H ₅ O) ₂ CHC≡CMgBr	H ₂ C=CH[(C ₂ H ₅ O) ₂ CHC≡C]CHOH	423
H ₂ C=CHCHO	C ₆ H ₅ (CH ₂) ₂ MgBr	H ₂ C=CH[C ₆ H ₅ (CH ₂) ₂]CHOH (>57%)	69
H ₂ C=CHCHO	C ₆ H ₅ (CH ₂) ₃ MgBr	H ₂ C=CH[C ₆ H ₅ (CH ₂) ₃]CHOH (57%)	69
C₃H₄OCl₂			
ClCH ₂ CHClCHO	(≡CMgBr) ₂	HC≡C(ClCH ₂ CHCl)CHOH	391
C₃H₅OCl			
ClCH ₂ CH ₂ CHO	CH ₃ MgI	CH ₃ (ClCH ₂ CH ₂)CHOH	98,86
ClCH ₂ CH ₂ CHO	(≡CMgBr) ₂	HC≡C(ClCH ₂ CH ₂)CHOH	391
ClCH ₂ CH ₂ CHO	C ₂ H ₅ MgBr	ClCH ₂ CH ₂ (C ₂ H ₅)CHOH	98
ClCH ₂ CH ₂ CHO	<i>n</i> -C ₃ H ₇ MgBr	ClCH ₂ CH ₂ (<i>n</i> -C ₃ H ₇)CHOH	98,16
ClCH ₂ CH ₂ CHO	<i>i</i> -C ₅ H ₁₁ MgBr	ClCH ₂ CH ₂ (<i>i</i> -C ₅ H ₁₁)CHOH	98
ClCH ₂ CH ₂ CHO (8.3 g., 0.09 mole)	4-ClC ₁₀ H ₆ -1-MgI (28.9 g., 0.1 mole C ₁₀ H ₆ ICl)	ClCH ₂ CH ₂ (4-Cl-1-C ₁₀ H ₆)CHOH	161
ClCH ₂ CH ₂ CHO	4-CH ₃ OC ₁₀ H ₆ -1-MgBr	ClCH ₂ CH ₂ (4-CH ₃ O-1-C ₁₀ H ₆)CHOH	161
C₃H₆O			
C ₂ H ₅ CHO	(≡CMgBr) ₂	[≡CCH(OH)C ₂ H ₅] ₂ (<70%)	370
C ₂ H ₅ CHO	(≡CMgBr) ₂	HC≡C(C ₂ H ₅)CHOH	392
C ₂ H ₅ CHO (58.0 g., 1.0 mole)	H ₂ C=CHCH ₂ MgCl (40.0 g. Mg)	C ₂ H ₅ (H ₂ C=CHCH ₂)CHOH (78.2 g., 0.782 mole, 78%)	411

* X = Br, Cl.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₆O (cont.)			
C ₂ H ₅ CHO	H ₂ C=CHCH ₂ MgBr	C ₂ H ₅ (H ₂ C=CHCH ₂)CHOH (62%, crude; 52%, purified)	136,258
C ₂ H ₅ CHO	Butenyl-MgBr*	C ₂ H ₅ [CH ₂ =CHCH(CH ₃)]CHOH (25%)	258
C ₂ H ₅ CHO	<i>s</i> -C ₄ H ₉ MgCl	C ₂ H ₅ (<i>s</i> -C ₄ H ₉)CHOH (65%)	83
C ₂ H ₅ CHO (1.65 mole)	<i>t</i> -C ₄ H ₉ MgCl (5 moles C ₄ H ₉ Cl)	C ₂ H ₅ (<i>t</i> -C ₄ H ₉)CHOH (60%)	84
C ₂ H ₅ CHO	<i>i</i> -C ₄ H ₉ MgCl	C ₂ H ₅ (<i>i</i> -C ₄ H ₉)CHOH (26%)	359,385
C ₂ H ₅ CHO (116 g.)	CH ₃ O(CH ₂) ₃ MgCl (202 g. C ₄ H ₉ ClO)	C ₂ H ₅ [CH ₃ O(CH ₂) ₃]CHOH	87
C ₂ H ₅ CHO	(CH ₂) ₄ CHMgBr	C ₂ H ₅ [(CH ₂) ₄ CH]CHOH (19.5%)	85
C ₂ H ₅ CHO (60 g.)	4-BrC ₆ H ₄ MgBr	C ₂ H ₅ (4-BrC ₆ H ₄)CHOH (95-100 g.)	277
C ₂ H ₅ CHO	C ₆ H ₅ MgBr	C ₂ H ₅ (C ₆ H ₅)CHOH	247
C ₂ H ₅ CHO	<i>n</i> -C ₆ H ₁₃ MgI	C ₂ H ₅ (<i>n</i> -C ₆ H ₁₃)CHOH (<i>ca.</i> 50%)	106
C ₂ H ₅ CHO (128 g.)	3-F ₃ CC ₆ H ₄ MgBr (450 g. C ₇ H ₄ BrF ₃)	C ₂ H ₅ (3-F ₃ CC ₆ H ₄)CHOH (300 g., 73%)	15
C ₂ H ₅ CHO	2-CH ₃ C ₆ H ₄ MgBr	C ₂ H ₅ (2-CH ₃ C ₆ H ₄)CHOH	206
C ₂ H ₅ CHO	3-CH ₃ C ₆ H ₄ MgBr	C ₂ H ₅ (3-CH ₃ C ₆ H ₄)CHOH	206
C ₂ H ₅ CHO (0.50 mole)	C ₆ H ₅ CH ₂ MgCl (0.57 mole)	C ₂ H ₅ (C ₆ H ₅ CH ₂)CHOH (35%); 2-C ₂ H ₅ CH(OH)C ₆ H ₄ CH ₂ CH(OH)C ₂ H ₅ (62%)	454
C ₂ H ₅ CHO	C ₆ H ₅ C≡CMgX	C ₂ H ₅ (C ₆ H ₅ C≡C)CHOH (52%)	215
C ₂ H ₅ CHO	(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)MgBr	C ₂ H ₅ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)]CHOH	77
C ₂ H ₅ CHO	1-Indenyl-MgBr	Ethyl-1-indenylmethanol (61%)	60
C ₂ H ₅ CHO (16 g.)	4-CH ₃ CH=CHC ₆ H ₄ MgBr	C ₂ H ₅ (4-CH ₃ CH=CHC ₆ H ₄)CHOH (10 g.)	278
C ₂ H ₅ CHO (25.7 g.)	2-C ₆ H ₅ C ₆ H ₄ MgBr (51.5 g. C ₁₂ H ₉ Br)	C ₂ H ₅ (2-C ₆ H ₅ C ₆ H ₄)CHOH (25.0 g., 60%)	430
C ₂ H ₅ CHO (0.2 mole)	4-(C ₂ H ₅) ₃ SiC ₆ H ₄ MgBr (0.1 mole C ₁₂ H ₁₉ BrSi)	C ₂ H ₅ [4-(C ₂ H ₅) ₃ SiC ₆ H ₄]CHOH ("very poor yield")	125

* From crotyl bromide (CH₃CH=CHCH₂Br).

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄HOF₇			
<i>n</i> -C ₃ F ₇ CHO (0.2-0.3 mole)	C ₂ H ₅ MgI (0.4-0.6 mole)	C ₂ H ₅ (<i>n</i> -C ₃ F ₇)CHOH (19.0%); <i>n</i> -C ₃ F ₇ CH ₂ OH (61.0%)	436
C₄H₂O₃Br₂			
HO ₂ CCBr=CBrCHO (10.4 g.)	CH ₃ MgI (26.5 g.)	3,4-Dibromo-5-methyldihydrofuran-2-one ("not over 50%")	302
HO ₂ CCBr=CBrCHO	C ₂ H ₅ MgBr	3,4-Dibromo-5-ethyldihydrofuran-2-one ("not over 50%")	302
C₄H₂O₃Cl₂			
HO ₂ CCCl=CClCHO	CH ₃ MgI	3,4-Dichloro-5-methyldihydrofuran-2-one	302
HO ₂ CCCl=CClCHO	C ₂ H ₅ MgBr	3,4-Dichloro-5-ethyldihydrofuran-2-one	302
C₄H₅OCl₃			
CH ₃ CHClCCl ₂ CHO (0.25 mole)	2-Thienyl-MgBr (0.25 mole C ₄ H ₃ BrS)	CH ₃ CHClCCl ₂ (<i>α</i> -C ₄ H ₃ S)CHOH (48 g., 74%)	97
CH ₃ CHClCCl ₂ CHO (0.25 mole)	C ₆ H ₅ MgBr (0.25 mole C ₆ H ₅ Br)	CH ₃ CHClCCl ₂ (C ₆ H ₅)CHOH (45 g., 71.1%); CH ₃ CHClCCl ₂ CHO · H ₂ O (5 g.); (C ₆ H ₅ —) ₂ (1.3 g.); residue (2.0 g.)	96
CH ₃ CHClCCl ₂ CHO (0.25 mole)	(CH ₂) ₅ CHMgBr (0.25 mole C ₆ H ₁₁ Br)	CH ₃ CHClCCl ₂ CHO · H ₂ O (8.5-9.0 g.); CH ₃ CHClCCl ₂ CH ₂ OH (22.5-23.0 g.); C ₆ H ₁₀ (26.0-27.5 g. C ₆ H ₁₀ Br ₂); tar (3.0-4.0 g.)	96
CH ₃ CHClCCl ₂ CHO (0.25 mole)	<i>n</i> -C ₆ H ₁₃ MgBr (0.25 mole C ₆ H ₁₃ Br)	CH ₃ CHClCCl ₂ CHO · H ₂ O (6.0-7.0 g.); CH ₃ CHClCCl ₂ CH ₂ OH (27.0-28.5 g.); C ₆ H ₁₂ (31.5-33.0 g. C ₆ H ₁₂ Br ₂); tar (2.5-4.0 g.)	96
CH ₃ CHClCCl ₂ CHO (0.25 mole)	C ₆ H ₅ CH ₂ MgCl (0.25 mole C ₆ H ₇ Cl)	CH ₃ CHClCCl ₂ CHO · H ₂ O (15.5 g.); (C ₆ H ₅ CH ₂ —) ₂ (13.7 g.); tar (14.0 g.)	96

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₅OCl₃ (cont.)			
CH ₃ CHClCCl ₂ CHO	C ₆ H ₅ C≡CMgBr	CH ₃ CHClCCl ₂ (C ₆ H ₅ C≡C)CHOH (70%)	148
CH ₃ CHClCCl ₂ CHO (0.25 mole)	C ₆ H ₅ (CH ₂) ₂ MgBr (0.25 mole C ₈ H ₉ Br)	CH ₃ CHClCCl ₂ CHO·H ₂ O (5.0-6.0 g.); CH ₃ CHClCCl ₂ CH ₂ OH (21.5-22.5 g.); C ₈ H ₈ (32.0-33.0 g. C ₈ H ₈ Br ₂); tar (6.5-7.0 g.)	96
C₄H₆O			
CH ₃ CH=CHCHO (142 g., 2.02 moles)	CH ₃ MgCl (61 g. Mg)	CH ₃ (CH ₃ CH=CH)CHOH (81-86%)	53
CH ₃ CH=CHCHO	CH ₃ MgBr	CH ₃ (CH ₃ CH=CH)CHOH (30%)	240,146,343
CH ₃ CH=CHCHO	CH ₃ MgI	CH ₃ (CH ₃ CH=CH)CHOH	121,59,281
CH ₃ CH=CHCHO	CH ₃ MgI	CH ₃ (CH ₃ CH=CH)CHOH (90%)	194
CH ₃ CH=CHCHO (25 g.)	(≡CMgBr) ₂ (50 g. Mg)	H ₂ C≡C(CH ₃ CH=CH)CHOH (10 g.)*	393,395
CH ₃ CH=CHCHO (35 g.)	(≡CMgBr) ₂ (12 g. Mg)	[≡CCH(OH)CH=CHCH ₃] ₂ (30 g., crude)	397,81,420
CH ₃ CH=CHCHO	C ₂ H ₅ MgBr	C ₂ H ₅ (CH ₃ CH=CH)CHOH (65%)	280,146,281, 343
CH ₃ CH=CHCHO	C ₂ H ₅ MgBr (excess)	C ₂ H ₅ (CH ₃ CH=CH)CHOH (70.3%); CH ₃ (C ₂ H ₅)CHCH ₂ CHO (0.1%); "com- plex products" (11.4%)	309,272
CH ₃ CH=CHCHO	C ₂ H ₅ MgBr	C ₂ H ₅ (CH ₃ CH=CH)CHOH (90%)	194
CH ₃ CH=CHCHO	H ₂ C=CHCH ₂ MgBr	CH ₃ CH=CH(H ₂ C=CHCH ₂)CHOH (82%, crude)	136,82,181, 258,264
CH ₃ CH=CHCHO	H ₂ C=CHCH ₂ MgBr (excess)	H ₂ C=CHCH ₂ (CH ₃ CH=CH)CHOH; CH ₃ (H ₂ C=CHCH ₂)CHCH ₂ CHO (trace)	309
CH ₃ CH=CHCHO	<i>n</i> -C ₃ H ₇ MgCl	CH ₃ CH=CH(<i>n</i> -C ₃ H ₇)CHOH (74%)	6
CH ₃ CH=CHCHO	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ CH=CH(<i>n</i> -C ₃ H ₇)CHOH (46%)	240,146,280, 281,343

* Hydrolysis with NH₄Cl; acid isomerizes the product (see: Jones and McCombie, *J. Chem. Soc.*, 1943, 261-4).

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₄H₆O (<i>cont.</i>)			
CH ₃ CH=CHCHO	<i>n</i> -C ₃ H ₇ MgBr (excess)	CH ₃ CH=CH(<i>n</i> -C ₃ H ₇)CHOH (78.3%); CH ₃ (<i>n</i> -C ₃ H ₇)CHCH ₂ CHO (trace); "com- plex products" (7.6%)	309
CH ₃ CH=CHCHO	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ CH=CH(<i>i</i> -C ₃ H ₇)CHOH (<i>ca.</i> 30%)	281,343,350
CH ₃ CH=CHCHO	<i>i</i> -C ₃ H ₇ MgBr (excess)	CH ₃ CH=CH(<i>i</i> -C ₃ H ₇)CHOH (46.5%); CH ₃ (<i>i</i> -C ₃ H ₇)CHCH ₂ CHO (0.3%); "com- plex products" (34.1%)	309
CH ₃ CH=CHCHO (19 g.)	H ₂ C=CHC≡CMgBr (23 g. C ₄ H ₄)	CH ₃ CH=CH(H ₂ C=CHC≡C)CHOH (12 g.)	406
CH ₃ CH=CHCHO	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ CH=CH(<i>n</i> -C ₄ H ₉)CHOH (51%)	240
CH ₃ CH=CHCHO	<i>i</i> -C ₄ H ₉ MgBr	CH ₃ CH=CH(<i>i</i> -C ₄ H ₉)CHOH (<i>ca.</i> 30%)	281,343
CH ₃ CH=CHCHO (10 g.)	<i>i</i> -C ₄ H ₉ MgBr (22 g. C ₄ H ₉ Br)	CH ₃ CH=CH(<i>i</i> -C ₄ H ₉)CHOH (3.4 g., crude); CH ₃ CH=CHCH ₂ OH (trace); residue (2.1 g.); slow C ₄ H ₈ - evolution*	138,281
CH ₃ CH=CHCHO (10 g.)	<i>i</i> -C ₄ H ₉ MgBr (22 g. C ₄ H ₉ Br)	CH ₃ CH=CH(<i>i</i> -C ₄ H ₉)CHOH (2.7 g., crude); CH ₃ CH=CHCH ₂ OH (2.0 g., crude); residue (2.8 g.); C ₄ H ₈ †	138
CH ₃ CH=CHCHO (10 g.)	<i>i</i> -C ₄ H ₉ MgI (29 g. C ₄ H ₉ I)	CH ₃ CH=CH(<i>i</i> -C ₄ H ₉)CHOH (0.5 g., pure); CH ₃ CH=CHCH ₂ OH (1.0 g., crude); residue (6.0 g.); C ₄ H ₈	138
CH ₃ CH=CHCHO (10 g.)	<i>s</i> -C ₄ H ₉ MgBr (22 g. C ₄ H ₉ Br)	CH ₃ CH=CH(<i>s</i> -C ₄ H ₉)CHOH (9 g. pure); no olefin; no CH ₃ CH=CHCH ₂ OH‡	138

* One and one-half hour at room temperature.

† One hour reflux Hess and Wustrow (138) report other similar experiments in various solvents and at various temperatures.

‡ Reaction at 0°.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₄H₆O (cont.)			
CH ₃ CH=CHCHO (10 g.)	<i>s</i> -C ₄ H ₉ MgBr (22 g. C ₄ H ₉ Br)	CH ₃ CH=CH(<i>s</i> -C ₄ H ₉)CHOH (2.8 g., crude); CH ₃ CH=CHCH ₂ OH (1.1 g., crude); residue (1.6 g.); slow C ₄ H ₈ -evolution*	138
CH ₃ CH=CHCHO (10 g.)	<i>s</i> -C ₄ H ₉ MgBr (22 g. C ₄ H ₉ Br)	CH ₃ CH=CHCH ₂ OH (0.6 g., crude); (CH ₃ CH=CHCH ₂) ₂ O; other high-boiling products; C ₄ H ₈ (ca. 1.1 l.) [†]	138
CH ₃ CH=CHCHO	<i>t</i> -C ₄ H ₉ MgCl	CH ₃ CH=CH(<i>t</i> -C ₄ H ₉)CHOH (3.4%)	240
CH ₃ CH=CHCHO (20 g.)	<i>t</i> -C ₄ H ₉ MgCl (75 g. C ₄ H ₉ Cl)	CH ₃ CH=CH(<i>t</i> -C ₄ H ₉)CHOH (30.6%); CH ₃ (<i>t</i> -C ₄ H ₉)CHCH ₂ CHO (20.3%); "complex products" (39.3%)	308,309
CH ₃ CH=CHCHO	<i>t</i> -C ₄ H ₉ MgBr	CH ₃ CH=CH(<i>t</i> -C ₄ H ₉)CHOH (3%); CH ₃ (<i>t</i> -C ₄ H ₉)CHCH ₂ CHO (10.8%); "complex products" (55.4%)	309
CH ₃ CH=CHCHO (63 g.)	H ₂ C=C(CH ₃)C≡CMgBr (67 g. C ₅ H ₆)	CH ₃ CH=CH[H ₂ C=C(CH ₃)C≡C]CHOH (58 g.)	406
CH ₃ CH=CHCHO	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ CH=CH(<i>i</i> -C ₅ H ₁₁)CHOH (45%)	121,343
CH ₃ CH=CHCHO (28 g.)	<i>t</i> -C ₅ H ₁₁ MgCl (86 g. C ₅ H ₁₁ Cl)	CH ₃ CH=CH(<i>t</i> -C ₅ H ₁₁)CHOH (16.3%); CH ₃ (<i>t</i> -C ₅ H ₁₁)CHCH ₂ CHO (22.6%); "complex products" (45.7%)	309
CH ₃ CH=CHCHO	C ₆ H ₅ MgBr (excess)	CH ₃ CH=CH(C ₆ H ₅)CHOH (ca. 90%); CH ₃ (C ₆ H ₅)CHCH ₂ CHO (0.1%); "complex products" (7.1%)	309
CH ₃ CH=CHCHO (35 g.)	C ₆ H ₅ MgBr (94 g. C ₆ H ₅ Br)	CH ₃ CH=CH(C ₆ H ₅)CHOH (51 g., 70%)	40,61
CH ₃ CH=CHCHO (18 g.)	CH ₃ CH=C(CH ₃)C≡CMgBr (20 g. C ₆ H ₈)	CH ₃ CH=CH[CH ₃ CH=C(CH ₃)C≡C]CHOH (31 g., 80%)	407

* Twenty-four hours at room temperature.

[†] Removal of ether; one hour at 110°.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₆O (<i>cont.</i>)			
CH ₃ CH=CHCHO (8.8 g.)	CH ₃ CH=CHCH(OMgBr)C≡CMgBr (12.0 g. C ₆ H ₈ O)	[≡CCH(OH)CH=CHCH ₃] ₂ (9.8 g., 40%)	398
CH ₃ CH=CHCHO	<i>n</i> -C ₄ H ₉ C≡CMgBr	CH ₃ CH=CH(<i>n</i> -C ₄ H ₉ C≡C)CHOH	127
CH ₃ CH=CHCHO (17.5 g.)	(CH ₂) ₅ CHC≡CMgBr (31 g. C ₈ H ₁₂)	CH ₃ CH=CH[(CH ₂) ₅ CHC≡C]CHOH (52%)	126
CH ₃ CH=CHCHO	1-C ₁₀ H ₇ MgBr	CH ₃ CH=CH(1-C ₁₀ H ₇)CHOH	301
H ₂ C=C(CH ₃)CHO (70 g., 1 mole)	(≡CMgBr) ₂ (24 g. Mg)	[≡CCH(OH)C(CH ₃)=CH ₂] ₂ (42.9 g., 52%)	65
H ₂ C=C(CH ₃)CHO (3.10 g.)	(CH ₃) ₂ C=CHCH ₂ CH ₂ MgBr (7.35 g. C ₆ H ₁₁ Br)	H ₂ C=C(CH ₃)[(CH ₃) ₂ C=CHCH ₂ CH ₂]CHOH + olefin (aggregating 2.35 g. of which 78% was alcohol)	431
H ₂ C=C(CH ₃)CHO (3.1 g.)	<i>i</i> -C ₆ H ₁₃ MgBr (6.0 g. C ₆ H ₁₃ Br)	H ₂ C=C(CH ₃)(<i>i</i> -C ₆ H ₁₃)CHOH + olefin (equiv. to 86% alcohol)	431
C₄H₇OBr			
CH ₃ CHBrCH ₂ CHO	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (CH ₃ CHBrCH ₂)CHOH	200
C₄H₇OCl			
(CH ₃) ₂ CClCHO	CH ₃ MgBr	<i>i</i> -C ₃ H ₇ (CH ₃) ₂ COH (53%)	133,134
C₄H₈O			
<i>n</i> -C ₃ H ₇ CHO	(≡CMgBr) ₂	HC≡C(<i>n</i> -C ₃ H ₇)CHOH (20-23%)	392
<i>n</i> -C ₃ H ₇ CHO (216.2 g.)	(≡CMgBr) ₂ (1.54 mole)	[≡CCH(OH)- <i>n</i> -C ₃ H ₇] ₂ (213.0 g., 41.8%)	399
<i>n</i> -C ₃ H ₇ CHO	(≡CMgBr) ₂	[≡CCH(OH)- <i>n</i> -C ₃ H ₇] ₂ (70.2%)	370
<i>n</i> -C ₃ H ₇ CHO	HC≡CH + 2 C ₂ H ₅ MgBr	[≡CCH(OH)- <i>n</i> -C ₃ H ₇] ₂ (38%)	268
<i>n</i> -C ₃ H ₇ CHO	C ₂ H ₅ MgBr	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)CHOH	266
<i>n</i> -C ₃ H ₇ CHO	H ₂ C=CHCH ₂ MgBr	H ₂ C=CHCH ₂ (<i>n</i> -C ₃ H ₇)CHOH (66%, crude; 57% purified)	136,56,167, 181

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₄H₈O (<i>cont.</i>)			
<i>n</i> -C ₃ H ₇ CHO	<i>n</i> -C ₃ H ₇ MgBr	(<i>n</i> -C ₃ H ₇) ₂ CHOH (60–85%)*	326
<i>n</i> -C ₃ H ₇ CHO	<i>i</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₄ H ₉)CHOH (60–85%)*	326
<i>n</i> -C ₃ H ₇ CHO (48.0 g.)	<i>i</i> -C ₄ H ₉ MgBr (142.7 g. C ₄ H ₉ Br)	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₄ H ₉)CHOH (32.0%, crude); <i>n</i> -C ₄ H ₉ OH (51.7%, crude); C ₄ H ₈	267
<i>n</i> -C ₃ H ₇ CHO	<i>s</i> -C ₄ H ₉ MgCl	<i>n</i> -C ₃ H ₇ (<i>s</i> -C ₄ H ₉)CHOH (62%)	83
<i>n</i> -C ₃ H ₇ CHO (4.0 g.)	BrMgOCH ₂ CH=CHC≡CMgBr (4.5 g. C ₅ H ₆ O)	<i>n</i> -C ₃ H ₇ CH(OH)C≡CCH=CHCH ₂ OH (2.5 g., 30%)	394
<i>n</i> -C ₃ H ₇ CHO	(CH ₂) ₄ CHMgBr	<i>n</i> -C ₃ H ₇ [(CH ₂) ₄ CH]CHOH	85
<i>n</i> -C ₃ H ₇ CHO	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₅ H ₁₁)CHOH (33%)	271
<i>n</i> -C ₃ H ₇ CHO	4-BrC ₆ H ₄ MgBr	<i>n</i> -C ₃ H ₇ (4-BrC ₆ H ₄)CHOH (48%)	277
<i>n</i> -C ₃ H ₇ CHO (27.4 g.)	CH ₃ CH=C(CH ₃)C≡CMgBr (31.0 g. C ₆ H ₆)	<i>n</i> -C ₃ H ₇ [CH ₃ CH=C(CH ₃)C≡C]CHOH (37.0 g., 60%)	407
<i>n</i> -C ₃ H ₇ CHO (<i>ca.</i> 0.3 mole)	C ₆ H ₅ CH ₂ MgCl (<i>ca.</i> 0.4 mole)	<i>n</i> -C ₃ H ₇ (C ₆ H ₅ CH ₂)CHOH (40%); 2- <i>n</i> -C ₃ H ₇ CH(OH)C ₆ H ₄ CH ₂ CH(OH)- <i>n</i> -C ₃ H ₇ (33%)	454
<i>n</i> -C ₃ H ₇ CHO	C ₆ H ₅ C≡CMgX	<i>n</i> -C ₃ H ₇ (C ₆ H ₅ C≡C)CHOH (83%)	215
<i>n</i> -C ₃ H ₇ CHO (9.0 g.)	CH ₃ CH=CHCH(OMgBr)C≡CMgBr (12.5 g. C ₆ H ₈ O)	<i>n</i> -C ₃ H ₇ CH(OH)C≡CCH(OH)CH=CHCH ₃ (12.0 g., 55%)	398
<i>n</i> -C ₃ H ₇ CHO	C ₆ H ₅ CH(CO ₂ Na)MgCl [†]	<i>n</i> -C ₃ H ₇ CH(OH)CH(C ₆ H ₅)CO ₂ H	158
<i>n</i> -C ₃ H ₇ CHO (30 g.)	<i>n</i> -C ₉ H ₁₉ MgBr (123 g. C ₉ H ₁₉ Br)	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₉ H ₁₉)CHOH (60 g.)	269
<i>n</i> -C ₃ H ₇ CHO (60 g.)	<i>n</i> -C ₁₀ H ₂₁ MgBr (270 g. C ₁₀ H ₂₁ Br)	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₁₀ H ₂₁)CHOH (117 g.)	269
<i>n</i> -C ₃ H ₇ CHO	2-C ₆ H ₅ C ₆ H ₄ MgI	<i>n</i> -C ₃ H ₇ (2-C ₆ H ₅ C ₆ H ₄)CHOH (>96%) [‡]	38

* Tuot (326) reports the yields for a series of carbinol preparations as ranging from 60% to 85%.

[†] In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135–54 (1931), this "Grignard reagent" should be formulated as an enolate.

[‡] The figure recorded represents overall yield of olefin obtained upon subsequent dehydration.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₄H₈O (<i>cont.</i>)			
<i>n</i> -C ₃ H ₇ CHO (0.2 mole)	4-(C ₂ H ₅) ₃ SiC ₆ H ₄ MgBr (0.1 mole C ₁₂ H ₁₉ BrSi)	<i>n</i> -C ₃ H ₇ [4-(C ₂ H ₅) ₃ SiC ₆ H ₄]CHOH ("very poor yield")	125
<i>n</i> -C ₃ H ₇ CHO (17 g.)	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₈ H ₁₇)CHMgI (90 g. C ₁₂ H ₂₅ I)	<i>n</i> -C ₃ H ₇ [<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₈ H ₁₇)CH]CHOH (10.5 g.)	269
<i>i</i> -C ₃ H ₇ CHO (36 g.)	(≡CMgBr) ₂ (12 g. Mg)	[≡CCH(OH)- <i>i</i> -C ₃ H ₇] ₂ (two isomers, totaling 27%)	65,149
<i>i</i> -C ₃ H ₇ CHO (33 g.)	C ₂ H ₅ MgBr (56 g. C ₂ H ₅ Br)	C ₂ H ₅ (<i>i</i> -C ₃ H ₇)CHOH (28 g., 68%)	255,385
<i>i</i> -C ₃ H ₇ CHO (72 g.)	H ₂ C=CHC≡CMgBr (from 110 g. C ₂ H ₅ Br).	<i>i</i> -C ₃ H ₇ (CH ₂ =CHC≡C)CHOH (56 g.)	244
<i>i</i> -C ₃ H ₇ CHO	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇)CHOH	242
<i>i</i> -C ₃ H ₇ CHO	<i>i</i> -C ₃ H ₇ MgBr	(<i>i</i> -C ₃ H ₇) ₂ CHOH; <i>i</i> -C ₄ H ₉ OH	385
<i>i</i> -C ₃ H ₇ CHO (264 g.)	(CH ₃) ₂ C=CHMgBr (500 g. C ₄ H ₇ Br)	<i>i</i> -C ₃ H ₇ [(CH ₃) ₂ C=CH]CHOH (102 g.); <i>i</i> -C ₄ H ₉ OH; <i>i</i> -C ₄ H ₈	190
<i>i</i> -C ₃ H ₇ CHO	<i>n</i> -C ₄ H ₉ MgBr	<i>i</i> -C ₃ H ₇ (<i>n</i> -C ₄ H ₉)CHOH; <i>i</i> -C ₄ H ₉ OH	242
<i>i</i> -C ₃ H ₇ CHO	<i>i</i> -C ₄ H ₉ MgBr	<i>i</i> -C ₃ H ₇ (<i>i</i> -C ₄ H ₉)CHOH	232,385
<i>i</i> -C ₃ H ₇ CHO (54 g., 0.75 mole)	<i>s</i> -C ₄ H ₉ MgBr (102 g., 0.75 mole C ₄ H ₉ Br)	Recovered aldehyde (22%); <i>i</i> -C ₄ H ₉ OH (37%); <i>i</i> -C ₃ H ₇ (<i>s</i> -C ₄ H ₉)CHOH (31%, crude); butenes in following propor- tions: 1-butene (34%); <i>cis</i> -2-butene (8%); <i>trans</i> -2-butene (58%)	367
<i>i</i> -C ₃ H ₇ CHO	<i>t</i> -C ₄ H ₉ MgCl	<i>i</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (25%); <i>i</i> -C ₃ H ₇ CH(OH)C(CH ₃) ₂ CHO (<i>ca.</i> 25%); <i>i</i> -C ₄ H ₉ OH (<i>ca.</i> 50%)	385
<i>i</i> -C ₃ H ₇ CHO	<i>t</i> -C ₄ H ₉ MgCl	<i>i</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (35%); <i>i</i> -C ₄ H ₉ OH (35%); solid, m. p. 51-52° (7.5%); (<i>t</i> -C ₄ H ₉ -) ₂ (1.5%)	353
<i>i</i> -C ₃ H ₇ CHO	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₃ H ₇ (<i>i</i> -C ₅ H ₁₁)CHOH (60-85%)*	326,232

* Tuot (326) reports the yields for a series of carbinols as ranging from 60% to 85%:

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₈O (<i>cont.</i>)			
<i>i</i> -C ₃ H ₇ CHO (107 g., 1.48 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.47 mole)	<i>i</i> -C ₄ H ₉ OH (84%)	358
<i>i</i> -C ₃ H ₇ CHO	CH ₃ (C ₂ H ₅)(BrMgO)CC≡CMgBr	<i>i</i> -C ₃ H ₇ [CH ₃ (C ₂ H ₅)C(OH)C≡C]CHOH (55%)	211
<i>i</i> -C ₃ H ₇ CHO	(CH ₂) ₅ CHMgBr	(CH ₂) ₅ CH(OH)- <i>i</i> -C ₃ H ₇	385
<i>i</i> -C ₃ H ₇ CHO	<i>i</i> -C ₆ H ₁₃ MgBr	<i>i</i> -C ₃ H ₇ (<i>i</i> -C ₆ H ₁₃)CHOH	232
<i>i</i> -C ₃ H ₇ CHO (<i>ca.</i> 0.3 mole)	C ₆ H ₅ CH ₂ MgCl (<i>ca.</i> 0.4 mole)	<i>i</i> -C ₃ H ₇ (C ₆ H ₅ CH ₂)CHOH (75%); 2- <i>i</i> -C ₃ H ₇ CH(OH)C ₆ H ₄ CH ₂ CH(OH)- <i>i</i> -C ₃ H ₇ (13%)	454,31
<i>i</i> -C ₃ H ₇ CHO	4-CH ₃ C ₆ H ₄ MgBr	<i>i</i> -C ₃ H ₇ (4-CH ₃ C ₆ H ₄)CHOH (53%)	377
<i>i</i> -C ₃ H ₇ CHO	C ₆ H ₅ CH(CO ₂ Na)MgCl*	<i>i</i> -C ₃ H ₇ CH(OH)CH(CO ₂ H)C ₆ H ₅ , mixture of A (m.p. 139-140°) and B (m.p. 171-172°) isomers (77%)	
<i>i</i> -C ₃ H ₇ CHO	C ₆ H ₅ (CH ₂) ₂ MgBr	<i>i</i> -C ₃ H ₇ (C ₆ H ₅ CH ₂ CH ₂)CHOH (59.5%)	32
<i>i</i> -C ₃ H ₇ CHO (0.2 mole)	4-(C ₂ H ₅) ₃ SiC ₆ H ₄ MgBr (0.1 mole C ₁₂ H ₁₉ BrSi)	<i>i</i> -C ₃ H ₇ [4-(C ₂ H ₅) ₃ SiC ₆ H ₄]CHOH ("very poor yield")	125
C₄H₈O₂			
CH ₃ CH(OH)CH ₂ CHO (1 mole)	CH ₃ MgI (2.25 mole)	CH ₃ [CH ₃ CH(OH)CH ₂]CHOH (6 g.)	100
CH ₃ CH(OH)CH ₂ CHO	C ₂ H ₅ MgBr (2.25 equiv.)	C ₂ H ₅ [CH ₃ CH(OH)CH ₂]CHOH	200
CH ₃ CH(OH)CH ₂ CHO	C ₂ H ₅ MgI (2.25 equiv.)	C ₂ H ₅ [CH ₃ OH(OH)CH ₂]CHOH	100
CH ₃ CH(OH)CH ₂ CHO	C ₆ H ₅ MgI (2.25 equiv.)	CH ₃ CH(OH)CH ₂ CH(C ₆ H ₅)OH; dehydr'n product	100
C₅H₄OS			
2-Thiophenecarboxaldehyde (112 g., 1.0 mole)	H ₂ C=CHCH ₂ MgBr (145 g., 1.2 mole C ₃ H ₅ Br)	H ₂ C=CHCH ₂ (<i>α</i> -C ₄ H ₅ S)CHOH (95 g., 61%)	412

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₄O₂			
Furfural	CH ₃ MgX	1- α -Furylethanol	331
Furfural	C ₂ H ₅ MgBr	1- α -Furyl-1-propanol; C ₂ H ₅ CH=CHCH ₂ COCH(C ₂ H ₅)OH	193
Furfural	H ₂ C=CHC \equiv CMgBr	1- α -Furylpent-4-en-2-yn-1-ol	244
Furfural	H ₂ C=CHCH ₂ Br + Mg	1- α -Furylbut-3-en-1-ol (78%)	306
Furfural	<i>n</i> -C ₃ H ₇ MgBr	1- α -Furyl-1-butanol	164
Furfural	<i>n</i> -C ₃ H ₇ MgX	1- α -Furyl-1-butanol, <i>n</i> -C ₃ H ₇ CH=CHCH ₂ COCH(<i>n</i> -C ₃ H ₇)OH	193
Furfural	<i>i</i> -C ₄ H ₉ MgX	1- α -Furyl-3-methyl-1-butanol; <i>i</i> -C ₄ H ₉ CH=CHCH ₂ COCH(<i>i</i> -C ₄ H ₉)OH	193
Furfural	<i>t</i> -C ₄ H ₉ MgX	1- α -Furyl-2,2-dimethyl-1-propanol	331
Furfural	<i>i</i> -C ₅ H ₁₁ MgBr	1- α -Furyl-4-methyl-1-pentanol (43%)	121
Furfural	C ₆ H ₅ CH ₂ MgBr	1- α -Furyl-2-phenylethanol (32%)	218
Furfural	(C ₂ H ₅) ₂ N(CH ₂) ₃ MgCl	1- α -Furyl-4-diethylamino-1-butanol	224
Furfural	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	1- α -Furyl-4-diethylamino-1-butanol	233
Furfural (12 g.)	C ₆ H ₅ CH(CO ₂ Na)MgCl*	α -Phenyl- β -(α -furyl)lactic acid (23 g.)	158
Furfural (7.0 g.)	1-C ₁₀ H ₇ MgBr (20.7 g. C ₁₀ H ₇ Br)	α -Furyl- α -naphthylmethanol	331
C₅H₆O			
H ₂ C=CHCH=CHCHO (33.5 g., 0.41 mole)	CH ₃ MgBr (58.0 g. CH ₃ Br)	CH ₃ (H ₂ C=CHCH=CH)CHOH (30.0 g., 75%)	364
H ₂ C=CHCH=CHCHO (41 g.)	H ₂ C=CHCH ₂ MgBr (80 g. C ₃ H ₅ Br)	"Octatrienol" (55 g., 90%)	365
C₅H₈O			
CH ₃ CH=C(CH ₃)CHO	CH ₃ MgBr	CH ₃ [CH ₃ CH=C(CH ₃)]CHOH	1

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₈O (<i>cont.</i>)			
CH ₃ CH=C(CH ₃)CHO	CH ₃ MgI	CH ₃ [CH ₃ CH=C(CH ₃)]CHOH	350
CH ₃ CH=C(CH ₃)CHO	C ₂ H ₅ MgBr	C ₂ H ₅ [CH ₃ CH=C(CH ₃)]CHOH	1
CH ₃ CH=C(CH ₃)CHO	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₅ H ₁₁ [CH ₃ CH=C(CH ₃)]CHOH	1
(CH ₃) ₂ CH=CHCHO (5 g.)	C ₁₀ H ₁₉ MgBr*	(CH ₃) ₂ CH=CH(C ₁₀ H ₁₉)CHOH (yield- ing 0.4 g. zingiberene on dehydr'n)	239
C₅H₉OBr			
<i>n</i> -C ₃ H ₇ CHBrCHO	C ₂ H ₅ MgBr	C ₉ H ₁₈	174
C₅H₁₀O			
<i>n</i> -C ₄ H ₉ CHO	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₄ H ₉)CHOH (60-85%) [†]	326
<i>n</i> -C ₄ H ₉ CHO	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (<i>n</i> -C ₄ H ₉)CHOH (60-85%) [†]	326
<i>n</i> -C ₄ H ₉ CHO	<i>n</i> -C ₄ H ₉ MgBr	(<i>n</i> -C ₄ H ₉) ₂ CHOH (65%)	213
<i>n</i> -C ₄ H ₉ CHO	<i>i</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ (<i>i</i> -C ₄ H ₉)CHOH (60-85%) [†]	326
<i>n</i> -C ₄ H ₉ CHO	(CH ₂) ₄ CHMgBr	<i>n</i> -C ₄ H ₉ [(CH ₂) ₄ CH]CHOH (18%)	85
<i>n</i> -C ₄ H ₉ CHO	<i>i</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₄ H ₉ (<i>i</i> -C ₅ H ₁₁)CHOH (60-85%) [†]	326
<i>n</i> -C ₄ H ₉ CHO (22 g.)	<i>n</i> -C ₅ H ₁₁ C≡CMgBr	<i>n</i> -C ₄ H ₉ (<i>n</i> -C ₅ H ₁₁ C≡C)CHOH (8 g.)	237
<i>n</i> -C ₄ H ₉ CHO	2-C ₆ H ₅ C ₆ H ₄ MgI	<i>n</i> -C ₄ H ₉ (2-C ₆ H ₅ C ₆ H ₄)CHOH (>42%) [†]	38
<i>i</i> -C ₄ H ₉ CHO	(≡CMgBr) ₂	[≡CCH(OH)- <i>i</i> -C ₄ H ₉] ₂	420
<i>i</i> -C ₄ H ₉ CHO	C ₂ H ₅ MgBr	C ₂ H ₅ (<i>i</i> -C ₄ H ₉)CHOH	266
<i>i</i> -C ₄ H ₉ CHO	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₄ H ₉)CHOH; <i>i</i> -C ₅ H ₁₁ OH	242
<i>i</i> -C ₄ H ₉ CHO	<i>n</i> -C ₃ H ₇ MgI	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₄ H ₉)CHOH ("very good yield")	50
<i>i</i> -C ₄ H ₉ CHO	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (<i>i</i> -C ₄ H ₉)CHOH (60-85%) [†]	326
<i>i</i> -C ₄ H ₉ CHO	<i>n</i> -C ₄ H ₉ CMgBr	<i>n</i> -C ₄ H ₉ (<i>i</i> -C ₄ H ₉)CHOH	213
<i>i</i> -C ₄ H ₉ CHO	<i>i</i> -C ₄ H ₉ MgBr	(<i>i</i> -C ₄ H ₉) ₂ CHOH (55%)	121
<i>i</i> -C ₄ H ₉ CHO	<i>i</i> -C ₄ H ₉ MgBr	(<i>i</i> -C ₄ H ₉) ₂ CHOH (60-85%) [†]	326

* From 5 g. 1-bromo-2-(4-methyl-3-cyclohexen-1-yl)propane.

[†] Tuot (326) reports the yields for a series of carbinol preparations as ranging from 60% to 85%.

‡ Figure recorded represents overall yield of olefin obtained upon subsequent dehydration.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₁₀O (cont.)			
<i>i</i> -C ₄ H ₉ CHO	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₄ H ₉ (<i>i</i> -C ₅ H ₁₁)CHOH (60–85%)*	326
<i>i</i> -C ₄ H ₉ CHO	(CH ₂) ₅ CHMgCl	<i>i</i> -C ₄ H ₉ [(CH ₂) ₅ CH]CHOH ("high yield")	388
<i>i</i> -C ₄ H ₉ CHO	<i>n</i> -C ₆ H ₁₃ MgX	<i>i</i> -C ₄ H ₉ (<i>n</i> -C ₆ H ₁₃)CHOH (73%)	349
<i>i</i> -C ₄ H ₉ CHO	C ₆ H ₅ CH ₂ Cl + Mg	<i>i</i> -C ₄ H ₉ (C ₆ H ₅ CH ₂)CHOH (35.1%)	270
<i>i</i> -C ₄ H ₉ CHO (28 g.)	<i>n</i> -C ₈ H ₁₇ MgBr (89 g. C ₈ H ₁₇ Br)	<i>i</i> -C ₅ H ₁₁ OH; C ₈ H ₁₆	267
<i>i</i> -C ₄ H ₉ CHO	CH ₃ (C ₆ H ₅)N(CH ₂) ₃ MgX	<i>i</i> -C ₄ H ₉ [CH ₃ (C ₆ H ₅)N(CH ₂) ₃]CHOH; [CH ₃ (C ₆ H ₅)N(CH ₂) ₃ —] ₂	346
<i>i</i> -C ₄ H ₉ CHO	2-C ₆ H ₅ C ₆ H ₄ MgI	<i>i</i> -C ₄ H ₉ (2-C ₆ H ₅ C ₆ H ₄)CHOH (>73%) [†]	38
<i>s</i> -C ₄ H ₉ CHO	C ₂ H ₅ MgBr	C ₂ H ₅ (<i>s</i> -C ₄ H ₉)CHOH	99
<i>s</i> -C ₄ H ₉ CHO (8 g., 0.09 mole)	<i>n</i> -C ₄ H ₉ MgBr (0.1 mole)	<i>n</i> -C ₄ H ₉ (<i>s</i> -C ₄ H ₉)CHOH (3.8 g., 38%)	368
<i>t</i> -C ₄ H ₉ CHO (0.12 mole)	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (0.06 mole); <i>t</i> -C ₄ H ₉ CH ₂ OH (trace)	55
<i>t</i> -C ₄ H ₅ CHO (0.12 mole)	<i>i</i> -C ₃ H ₇ MgCl	<i>i</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (0.04 mole); <i>t</i> -C ₄ H ₉ CH ₂ OH (0.01 mole)	55
<i>t</i> -C ₄ H ₉ CHO (0.2 mole)	<i>t</i> -C ₄ H ₉ MgCl	<i>t</i> -C ₄ H ₉ CH ₂ OH (0.13 mole)	55
C₅H₁₀O₂			
HOCH ₂ (CH ₃) ₂ CCHO (25 g.)	CH ₃ MgI (88 g. CH ₃ I)	CH ₃ [HOCH ₂ (CH ₃) ₂ C]CHOH (6 g.); CH ₄	100
HOCH ₂ (CH ₃) ₂ CCHO (15.8 g.)	C ₂ H ₅ MgI (49.0 g. C ₂ H ₅ I)	C ₂ H ₅ [HOCH ₂ (CH ₃) ₂ C]CHOH (6.0 g., crude)	100
HOCH ₂ (CH ₃) ₂ CCHO (15 g.)	C ₆ H ₅ MgBr (100 g. C ₆ H ₅ Br)	C ₆ H ₅ [HOCH ₂ (CH ₃) ₂ C]CHOH (11 g.)	100
C₆H₅ON			
2-Pyridinecarboxaldehyde	C ₂ H ₅ MgBr	1- α -Pyridyl-1-propanol (63%)	197

* Tuot (326) reports the yields for a series of carbinol preparations as ranging from 60% to 85%.

[†] Figure recorded represents overall yield of olefin obtained upon subsequent dehydration.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₅ON (<i>cont.</i>)			
3-Pyridinecarboxaldehyde	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	1-β-Pyridyl-4-diethylamino-1-butanol	233
C₆H₆O₂			
5-Methyl-2-furaldehyde	<i>i</i> -C ₃ H ₇ MgX	1-(5-Methyl-2-furyl)-1-butanol	330
C₆H₈O			
1-Cyclopentenecarboxaldehyde	CH ₃ MgBr (<i>ca.</i> 1.3 equiv.)	1-(1-Cyclopentenyl)ethanol (85-90%)	329
1-Cyclopentenecarboxaldehyde	C ₂ H ₅ MgBr (<i>ca.</i> 1.3 equiv.)	1-(1-Cyclopentenyl)-1-propanol (85-90%)	329
1-Cyclopentenecarboxaldehyde	<i>n</i> -C ₃ H ₇ MgBr (<i>ca.</i> 1.3 equiv.)	1-(1-Cyclopentenyl)-1-butanol (85-90%)	329
CH ₃ (CH=CH) ₂ CHO (22 g.)	(≡CMgBr) ₂ (6 g. Mg)	[≡CCH(OH)(CH=CH) ₂ CH ₃] ₂ (12 g., 42%)	400
CH ₃ (CH=CH) ₂ CHO (38 g.)	1-Cyclohexenylethynyl-MgBr (42 g. C ₈ H ₁₀)	1-(1-Cyclohexen-1-yl)-4,6-octadien- 1-yn-3-ol (36 g.)	126
C₆H₁₀O			
<i>n</i> -C ₃ H ₇ CH=CHCHO	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ [(<i>n</i> -C ₃ H ₇ CH=CH)CHOH (75%)]	72
C ₂ H ₅ CH=C(CH ₃)CHO	CH ₃ MgI	CH ₃ [C ₂ H ₅ CH=C(CH ₃)CHOH (65%)]	121
C ₂ H ₅ CH=C(CH ₃)CHO	C ₂ H ₅ MgBr	C ₂ H ₅ [C ₂ H ₅ CH=C(CH ₃)CHOH (88%)]	30,343
C ₂ H ₅ CH=C(CH ₃)CHO	<i>n</i> -C ₃ H ₇ MgCl	<i>n</i> -C ₃ H ₇ [C ₂ H ₅ CH=C(CH ₃)CHOH (83%)]	30,343
C ₂ H ₅ CH=C(CH ₃)CHO	<i>i</i> -C ₄ H ₉ MgBr	<i>i</i> -C ₄ H ₉ [C ₂ H ₅ CH=C(CH ₃)CHOH (67.5%)]	30
C ₂ H ₅ CH=C(CH ₃)CHO	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₅ H ₁₁ [C ₂ H ₅ CH=C(CH ₃)CHOH (80%)]	30
(CH ₂) ₄ CHCHO	<i>n</i> -C ₄ H ₉ MgCl	<i>n</i> -C ₄ H ₉ [(CH ₂) ₄ CH]CHOH (60%)	335
(CH ₂) ₄ CHCHO	C ₆ H ₅ CH ₂ CH ₂ MgBr	(CH ₂) ₄ CH(C ₆ H ₅ CH ₂ CH ₂)CHOH ("excellent yield")	413
C₆H₁₂O			
<i>n</i> -C ₅ H ₁₁ CHO	<i>n</i> -C ₁₀ H ₂₁ MgBr	<i>n</i> -C ₅ H ₁₁ (<i>n</i> -C ₁₀ H ₂₁)CHOH (60%)	8

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₂O (<i>cont.</i>)			
<i>n</i> -C ₅ H ₁₁ CHO	2-C ₆ H ₅ C ₆ H ₄ MgI	<i>n</i> -C ₅ H ₁₁ (2-C ₆ H ₅ C ₆ H ₄)CHOH (> 59%)*	38
<i>i</i> -C ₅ H ₁₁ CHO	(CH ₂) ₅ CHMgCl	<i>i</i> -C ₅ H ₁₁ [(CH ₂) ₅ CH]CHOH	288
CH ₃ (<i>n</i> -C ₃ H ₇)CHCHO	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₅ H ₁₁ [CH ₃ (<i>n</i> -C ₃ H ₇)CH]CHOH	173
(C ₂ H ₅) ₂ CHCHO (3.5 g., 0.25 mole)	<i>t</i> -C ₄ H ₉ MgCl (0.31 mole)	(C ₂ H ₅) ₂ CHCH ₂ OH (4.8 g.); <i>t</i> -C ₄ H ₉ [(C ₂ H ₅) ₂ CH]CHOH (24.0 g.)	358
(C ₂ H ₅) ₂ CHCHO (0.4 mole)	<i>t</i> -C ₅ H ₁₁ MgCl (0.5 mole)	(C ₂ H ₅) ₂ CHCH ₂ OH (67%); <i>t</i> -C ₅ H ₁₁ [(C ₂ H ₅) ₂ CH]CHOH (21%)	358
<i>t</i> -C ₅ H ₁₁ CHO (0.10 mole)	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (<i>t</i> -C ₅ H ₁₁)CHOH (0.045 mole); <i>t</i> -C ₅ H ₁₁ CH ₂ OH (0.015 mole)	55
<i>t</i> -C ₅ H ₁₁ CHO (0.09 mole)	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (<i>t</i> -C ₅ H ₁₁)CHOH (0.024 mole); <i>t</i> -C ₅ H ₁₁ CH ₂ OH (0.030 mole)	55
<i>t</i> -C ₅ H ₁₁ CHO (0.5 mole)	<i>t</i> -C ₄ H ₉ MgCl (0.11 mole Mg)	<i>t</i> -C ₅ H ₁₁ CH ₂ OH (0.03 mole)	55
C₆H₁₂O₂			
C ₂ H ₅ CH(OH)CH(CH ₃)CHO (1 mole)	CH ₃ MgI (2.5 moles CH ₃ I)	C ₂ H ₅ CH(OH)CH(CH ₃)CH(CH ₃)OH	100
C ₂ H ₅ CH(OH)CH(CH ₃)CHO	C ₂ H ₅ MgI	C ₂ H ₅ CH(OH)CH(CH ₃)CH(C ₂ H ₅)OH (70%)	100
C ₂ H ₅ CH(OH)CH(CH ₃)CHO (1 mole)	C ₆ H ₅ MgI (2.5 moles C ₆ H ₅ I)	C ₂ H ₅ CH(OH)CH(CH ₃)CH(C ₆ H ₅)OH	100
C₆H₁₂O₃			
(C ₂ H ₅ O) ₂ CHCHO	CH ₃ MgI	CH ₃ [(C ₂ H ₅ O) ₂ CH]CHOH (71%)	92
C₇HOCl₅			
C ₆ Cl ₅ CHO (14 g.)	CH ₃ MgI (9 g. CH ₃ I)	CH ₃ (C ₆ Cl ₅)CHOH (7.3 g.); recovered aldehyde (3.6 g.)	210
C ₆ Cl ₅ CHO (5 g.)	C ₆ H ₅ MgBr (4 g. C ₆ H ₅ Br)	C ₆ Cl ₅ (C ₆ H ₅)CHOH	210

* Figure recorded represents overall yield of olefin obtained upon subsequent dehydration.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₄OCl₂ (cont.)			
2,3-Cl ₂ C ₆ H ₃ CHO	CH ₃ MgI	CH ₃ (2,3-Cl ₂ C ₆ H ₃)CHOH (76%)	259
2,4-Cl ₂ C ₆ H ₃ CHO	CH ₃ MgI	CH ₃ (2,4-Cl ₂ C ₆ H ₃)CHOH (62%)	259
2,5-Cl ₂ C ₆ H ₃ CHO (110 g.)	CH ₃ MgBr	CH ₃ (2,5-Cl ₂ C ₆ H ₃)CHOH (110 g., 83%)	401
2,6-Cl ₂ C ₆ H ₃ CHO	CH ₃ MgI	CH ₃ (2,6-Cl ₂ C ₆ H ₃)CHOH (89%)	259
3,4-Cl ₂ C ₆ H ₃ CHO	CH ₃ MgI	CH ₃ (3,4-Cl ₂ C ₆ H ₃)CHOH (73%)	259
3,5-Cl ₂ C ₆ H ₃ CHO	CH ₃ MgI	CH ₃ (3,5-Cl ₂ C ₆ H ₃)CHOH (69%)	259
C₇H₅OBr			
2-BrC ₆ H ₄ CHO	CH ₃ MgI	CH ₃ (2-BrC ₆ H ₄)CHOH (73%)	259
3-BrC ₆ H ₄ CHO	CH ₃ MgI	CH ₃ (3-BrC ₆ H ₄)CHOH (74%)	259
4-BrC ₆ H ₄ CHO	CH ₃ MgI	CH ₃ (4-BrC ₆ H ₄)CHOH (64%)	259
4-BrC ₆ H ₄ CHO	CH ₃ MgI	CH ₃ (4-BrC ₆ H ₄)CHOH (95%)	277
4-BrC ₆ H ₄ CHO	CH ₃ MgBr	CH ₃ (4-BrC ₆ H ₄)CHOH	373
4-BrC ₆ H ₄ CHO	C ₂ H ₅ MgBr	C ₂ H ₅ (4-BrC ₆ H ₄)CHOH (90%)	277
4-BrC ₆ H ₄ CHO	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (4-BrC ₆ H ₄)CHOH (90%)	276,277
4-BrC ₆ H ₄ CHO	C ₆ H ₅ MgBr	4-BrC ₆ H ₄ (C ₆ H ₅)CHOH ("good yield")	253
C₇H₅OCl			
2-ClC ₆ H ₄ CHO (140.0 g.)	CH ₃ MgBr (26.7 g. Mg)	CH ₃ (2-ClC ₆ H ₄)CHOH (119.0 g., 76%)	401
2-ClC ₆ H ₄ CHO	CH ₃ MgI	CH ₃ (2-ClC ₆ H ₄)CHOH (69%)	259
2-ClC ₆ H ₄ CHO	C ₆ H ₅ CH ₂ MgCl	2-ClC ₆ H ₄ (C ₆ H ₅ CH ₂)CHOH (30%)	25
2-ClC ₆ H ₄ CHO	8-CH ₃ C ₁₀ H ₆ -1-MgBr	2-ClC ₆ H ₄ [8-CH ₃ -1-C ₁₀ H ₆]CHOH (44%)	90
3-ClC ₆ H ₄ CHO (142 g.)	CH ₃ MgBr	CH ₃ (3-ClC ₆ H ₄)CHOH (118 g., 76%)	401
3-ClC ₆ H ₄ CHO	C ₆ H ₅ (CH ₂) ₂ MgBr	3-ClC ₆ H ₄ [C ₆ H ₅ (CH ₂) ₂]CHOH (64%)	39
4-ClC ₆ H ₄ CHO (141 g.)	CH ₃ MgBr	CH ₃ (4-ClC ₆ H ₄)CHOH (134 g., 86%)	401
4-ClC ₆ H ₄ CHO	CH ₃ MgI	CH ₃ (4-ClC ₆ H ₄)CHOH (59%)	259

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₅OCl (<i>cont.</i>)			
4-ClC ₆ H ₄ CHO	C ₆ H ₅ CH(CO ₂ Na)MgCl*	4-ClC ₆ H ₄ CH(OH)CH(C ₆ H ₅)CO ₂ H (40%); 4-ClC ₆ H ₄ CO ₂ H; C ₆ H ₅ CO ₂ H	158
C₇H₅OF			
2-FC ₆ H ₄ CHO (99 g.)	CH ₃ MgBr	CH ₃ (2-FC ₆ H ₄)CHOH (87 g., 78%)	401
3-FC ₆ H ₄ CHO (99 g.)	CH ₃ MgBr	CH ₃ (3-FC ₆ H ₄)CHOH (83 g., 74%)	401
4-FC ₆ H ₄ CHO (99 g.)	CH ₃ MgBr	CH ₃ (4-FC ₆ H ₄)CHOH (94 g., 84%)	401
C₇H₅O₃N			
2-O ₂ NC ₆ H ₄ CHO	2-CH ₃ C ₆ H ₄ MgBr	2-O ₂ NC ₆ H ₄ (2-CH ₃ C ₆ H ₄)CHOH	255
3-O ₂ NC ₆ H ₄ CHO	<i>n</i> -C ₄ H ₉ MgBr	Tar	248
3-O ₂ NC ₆ H ₄ CHO (47 g., 0.312 mole)	C ₆ H ₅ MgBr (0.196 mole)	C ₆ H ₅ (3-O ₂ NC ₆ H ₄)CHOH (77%)	248
C₇H₆O			
C ₆ H ₅ CHO	CH ₃ MgI	CH ₃ (C ₆ H ₅)CHOH (<i>ca.</i> 78%)	121,119,375
C ₆ H ₅ CHO	CH ₃ MgI	CH ₃ (C ₆ H ₅)CHOH (93%)	105
C ₆ H ₅ CHO (excess)	CH ₃ MgI	CH ₃ COC ₆ H ₅ ; C ₆ H ₅ COCH=CHC ₆ H ₅ ; (C ₆ H ₅ CO) ₂ CH ₂	447,446
C ₆ H ₅ CHO	CH ₃ MgI	CH ₃ (C ₆ H ₅)CHOH (6 g.) (optically active, 0.30°; after 24 hrs., 0.18°) [†]	28
C ₆ H ₅ CHO	CH ₃ MgI	DL-CH ₃ (C ₆ H ₅)CHOH [†] (60-68%)	313
C ₆ H ₅ CHO	(≡CMgBr) ₂	HC≡C(C ₆ H ₅)CHOH (20-23%)	392,391

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

[†] Grignard reagent prepared in *N,N*-dimethylbornylamine. The present authors question the optical activity of the product.

‡ Grignard reagent prepared in (+)-2-methoxybutane.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₆O (<i>cont.</i>)			
C ₆ H ₅ CHO (20 g.) + (C ₆ H ₅) ₂ CO (30 g.)	(≡ CMgBr) ₂ (0.5 mole)	[≡ CC(C ₆ H ₅) ₂ OH] ₂ ; [≡ CCH(OH)C ₆ H ₅] ₂ ; 2 isomers; * HO(C ₆ H ₅) ₂ CC≡ CCH(C ₆ H ₅)OH*	294
C ₆ H ₅ CHO	(≡ CMgBr) ₂	[≡ CCH(OH)C ₆ H ₅] ₂ (< 70%)	370, 151, 327, 81, 139, 419, 422
C ₆ H ₅ CHO	C ₂ H ₅ MgBr	C ₂ H ₅ (C ₆ H ₅)CHOH (<i>ca.</i> 78%)	121, 105, 119, 137, 247, 254, 341, 375
C ₆ H ₅ CHO	C ₂ H ₅ MgBr	C ₂ H ₅ (C ₆ H ₅)CHOH; C ₆ H ₅ CH ₂ OH; residue†	229
C ₆ H ₅ CHO	C ₂ H ₅ MgI	C ₂ H ₅ (C ₆ H ₅)CHOH; C ₆ H ₅ CH ₂ OH; residue†	229, 137, 257
C ₆ H ₅ CHO (79 g., 1.5 equiv.)	C ₂ H ₅ MgI (78 g. C ₂ H ₅ I)	C ₆ H ₅ CH ₂ OH (<i>ca.</i> 16 g.); C ₂ H ₅ (C ₆ H ₅)CHOH; C ₂ H ₅ COC ₆ H ₅ ; (C ₆ H ₅ CO) ₂ CHCH ₃ (16 g., crude)	447
C ₆ H ₅ CHO	C ₂ H ₅ I + Mg	C ₂ H ₅ (C ₆ H ₅)CHOH (chief product); C ₆ H ₅ CH=CHCH ₃ ; [C ₂ H ₅ (C ₆ H ₅)CH] ₂ O	416
C ₆ H ₅ CHO	H ₂ C=CHCH ₂ Br + Mg	H ₂ C=CHCH ₂ (C ₆ H ₅)CHOH	180, 161
C ₆ H ₅ CHO	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CHOH (80%)	105, 119, 121, 254, 341
C ₆ H ₅ CHO (1.5 equiv.)	<i>n</i> -C ₃ H ₇ MgI (68 g. C ₃ H ₇ I)	(C ₆ H ₅ CO) ₂ CHC ₂ H ₅ (23 g., crude)	447
C ₆ H ₅ CHO	<i>n</i> -C ₃ H ₇ MgI	<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CHOH (<i>ca.</i> quant.)	177, 257
C ₆ H ₅ CHO	<i>n</i> -C ₃ H ₇ I + Mg	<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CHOH (chief product); C ₆ H ₅ CH=CHC ₂ H ₅ ; [<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CH] ₂ O	416

* Isolated as the corresponding 3,4-dibromo-2,5-dihydrofurans.

† Meisenheimer (229) reports results for experiments conducted under a wide variety of conditions.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₆O (<i>cont.</i>)			
C ₆ H ₅ CHO	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (C ₆ H ₅)CHOH	385
C ₆ H ₅ CHO	<i>i</i> -C ₃ H ₇ MgI	<i>i</i> -C ₃ H ₇ (C ₆ H ₅)CHOH	121
C ₆ H ₅ CHO (1.5 equiv.)	<i>i</i> -C ₃ H ₇ MgI	Rec. C ₆ H ₅ CHO; <i>i</i> -C ₃ H ₇ COC ₆ H ₅ ; <i>i</i> -C ₃ H ₇ (C ₆ H ₅)CHOH	447,446
C ₆ H ₅ CHO	H ₂ C=CHC≡CMgX	H ₂ C=CHC≡C(C ₆ H ₅)CHOH (73%)	369
C ₆ H ₅ CHO	Butenyl-MgBr*	H ₂ C=CHCH(CH ₃)CH(C ₆ H ₅)OH (<25%)	258
C ₆ H ₅ CHO	(CH ₃) ₂ C=CHMgBr	(CH ₃) ₂ C=CHCH(C ₆ H ₅)OH	191
C ₆ H ₅ CHO	<i>n</i> -C ₄ H ₉ MgCl	<i>n</i> -C ₄ H ₉ (C ₆ H ₅)CHOH (66%)	386
C ₆ H ₅ CHO	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ (C ₆ H ₅)CHOH	341
C ₆ H ₅ CHO (0.2 mole)	<i>i</i> -C ₄ H ₉ MgBr (0.2 mole C ₄ H ₉ Br)	Recovered C ₆ H ₅ CHO (20-27%); <i>i</i> -C ₄ H ₉ (C ₆ H ₅)CHOH (21 g.); residue (0.5 g.); C ₆ H ₅ CH ₂ OH (12%); (CH ₃) ₂ C=CH ₂	229,120
C ₆ H ₅ CHO (38.6 g.)	<i>s</i> -C ₄ H ₉ MgBr (50.0 g. C ₄ H ₉ Br)	<i>s</i> -C ₄ H ₉ (C ₆ H ₅)CHOH (60%)	432
C ₆ H ₅ CHO (53 g., 0.5 mole)	<i>t</i> -C ₄ H ₉ MgCl (92.5 g., 1 mole C ₄ H ₉ Cl)	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)CHOH (55-61%)	323
C ₆ H ₅ CHO (20 g.)	2,6-Pyridylidene-(MgBr) ₂	2,6-Bis(phenylhydroxymethyl)pyridine (4 g., crude); 2-(phenylhydroxy- methyl)pyridine (1 g.)	273
C ₆ H ₅ CHO (16 g.)	2-Pyridyl-MgBr (16 g. C ₅ H ₄ BrN)	Phenyl-2-pyridylmethanol (9 g., 49%)	260
C ₆ H ₅ CHO	(CH ₂) ₄ CHMgBr	(CH ₂) ₄ CH(C ₆ H ₅)CHOH (7%)	85
C ₆ H ₅ CHO	(CH ₂) ₄ CHMgCl	(CH ₂) ₄ CH(C ₆ H ₅)CHOH; "1,3-dibenzylidenecyclopentanone"	192
C ₆ H ₅ CHO	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₅ H ₁₁ (C ₆ H ₅)CHOH (56%)	121
C ₆ H ₅ CHO (106 g.)	<i>s</i> -C ₄ H ₉ CH ₂ MgBr (151 g. C ₅ H ₁₁ Br)	<i>s</i> -C ₄ H ₉ CH ₂ (C ₆ H ₅)CHOH (40 g.)	63
C ₆ H ₅ CHO (15.9 g.)	(CH ₃) ₂ N(CH ₂) ₃ MgCl (30 g. C ₅ H ₁₂ ClN)	(CH ₃) ₂ N(CH ₂) ₃ CH(C ₆ H ₅)OH (70%)	224
C ₆ H ₅ CHO	(CH ₃) ₂ N(CH ₂) ₃ Cl + Mg	(CH ₃) ₂ N(CH ₂) ₃ CH(C ₆ H ₅)OH	233
C ₆ H ₅ CHO	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ (C ₆ H ₅)CHOH	234
C ₆ H ₅ CHO	4-ClC ₆ H ₄ MgI	4-ClC ₆ H ₄ (C ₆ H ₅)CHOH	234

* From crotyl bromide (CH₃CH=CHCH₂Br).

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₇H₆O (<i>cont.</i>)			
C ₆ H ₅ CHO	3-FC ₆ H ₄ MgBr	3-FC ₆ H ₄ (C ₆ H ₅)CHOH (47%)	14
C ₆ H ₅ CHO	4-FC ₆ H ₄ MgBr	4-FC ₆ H ₄ (C ₆ H ₅)CHOH (58%)	14,378
C ₆ H ₅ CHO (1.0 equiv.)	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHOH (55%)	447,289,290
C ₆ H ₅ CHO (50 g.)	C ₆ H ₅ MgBr (24 g. Mg + 75 g. C ₆ H ₅ Br)	[(C ₆ H ₅) ₂ CH—] ₂ (30 g.); (C ₆ H ₅) ₂ CHOH	447
C ₆ H ₅ CHO (106 g., 2.0 equiv.)	C ₆ H ₅ MgBr (75 g. C ₆ H ₅ Br)	Rec. C ₆ H ₅ CHO; C ₆ H ₅ CH ₂ OH; (C ₆ H ₅) ₂ CO; [(C ₆ H ₅) ₂ CH—] ₂	446,447
C ₆ H ₅ CHO (13.0 g.)	CH ₃ CH=CHCH(OMgBr)C≡CMgBr (12.0 g. C ₆ H ₆ O)	C ₆ H ₅ CH(OH)C≡CCH(OH)CH=CHCH ₃ (10.5 g., 40%)	398
C ₆ H ₅ CHO	<i>n</i> -C ₄ H ₉ C≡CMgBr	C ₆ H ₅ (<i>n</i> -C ₄ H ₉ C≡C)CHOH (62%)	44
C ₆ H ₅ CHO	(CH ₂) ₅ CHMgCl	C ₆ H ₅ [(CH ₂) ₅ CH]CHOH	388
C ₆ H ₅ CHO (6.5 g.)	(CH ₂) ₅ CHMgBr (10.0 g. C ₆ H ₁₁ Br)	C ₆ H ₅ [(CH ₂) ₅ CH]CHOH (70%)	342,288,440
C ₆ H ₅ CHO	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ (C ₆ H ₅ CH ₂)CHOH* (95%)	298,128,305, 324,327
C ₆ H ₅ CHO (0.38 mole)	C ₆ H ₅ CH ₂ MgCl (0.40 mole)	C ₆ H ₅ (C ₆ H ₅ CH ₂)CHOH (64.0 g., 0.32 mole); 1,3-diphenylisochroman (1.8 g.) [†]	453
C ₆ H ₅ CHO (0.38 mole)	C ₆ H ₅ CH ₂ MgCl (0.40 mole)	C ₆ H ₅ (C ₆ H ₅ CH ₂)CHOH (33.9 g., 0.17 mole); 1,3-diphenylisochroman (20.3 g., 0.067 mole) [†]	453
C ₆ H ₅ CHO (excess)	C ₆ H ₅ CH ₂ MgBr	C ₆ H ₅ (C ₆ H ₅ CO) ₂ CH; C ₆ H ₅ COCH ₂ C ₆ H ₅ ; C ₆ H ₅ (C ₆ H ₅ CH ₂)CHOH	447
C ₆ H ₅ CHO	2-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ (2-CH ₃ C ₆ H ₄)CHOH	325,253
C ₆ H ₅ CHO	3-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ (3-CH ₃ C ₆ H ₄)CHOH	253
C ₆ H ₅ CHO	4-CH ₃ C ₆ H ₄ MgI (excess)	C ₆ H ₅ (4-CH ₃ C ₆ H ₄)CHOH	447

* Concerning "abnormal" products obtained under other experimental conditions see: Schmidlin and Garcia-Banús, (298); Garcia-Banús, *Anales. soc. españ. fís. quim.*, 26, 372-98 (1928); *Chem. Abstr.*, 23, 2178-80 (1929).

[†] Normal addition.

! Inverse addition.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₇H₆O (<i>cont.</i>)			
C ₆ H ₅ CHO	4-CH ₃ C ₆ H ₄ MgI (0.5 equiv.)	C ₆ H ₅ CH ₂ OH; C ₆ H ₅ COC ₆ H ₄ -4-CH ₃	447
C ₆ H ₅ CHO	3-CH ₃ OC ₆ H ₄ MgBr	C ₆ H ₅ (3-CH ₃ OC ₆ H ₄)CHOH (55%)	14
C ₆ H ₅ CHO (12.7 g.)	C ₆ H ₅ SO ₂ CH ₂ MgBr (15.0 g. C ₇ H ₈ O ₂ S)	C ₆ H ₅ (C ₆ H ₅ SO ₂ CH ₂)CHOH (22.7 g., 90% crude; 18.5 g., 73% pure)	437
C ₆ H ₅ CHO	(CH ₂) ₅ CHCH ₂ MgI	C ₆ H ₅ [(CH ₂) ₅ CHCH ₂]CHOH (36%)	339
C ₆ H ₅ CHO	(CH ₂) ₅ CHCH ₂ MgBr	C ₆ H ₅ [(CH ₂) ₅ CHCH ₂]CHOH (60%)	265
C ₆ H ₅ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ MgCl	C ₆ H ₅ [(C ₂ H ₅) ₂ N(CH ₂) ₃]CHOH (67%)	224
C ₆ H ₅ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	C ₆ H ₅ [(C ₂ H ₅) ₂ N(CH ₂) ₃]CHOH	233
C ₆ H ₅ CHO	C ₆ H ₅ C≡CMgBr	C ₆ H ₅ (C ₆ H ₅ C≡C)CHOH	44
C ₆ H ₅ CHO	C ₆ H ₅ CH(CO ₂ Na)MgCl*	C ₆ H ₅ CH(OH)CH(CO ₂ H)C ₆ H ₅ (60%)	158
C ₆ H ₅ CHO	C ₆ H ₅ (CH ₂) ₂ MgBr (10 g. C ₈ H ₉ Br)	C ₆ H ₅ [C ₆ H ₅ (CH ₂) ₂]CHOH (80 g.)	39
C ₆ H ₅ CHO (5 ml.)	2,3-(CH ₃) ₂ C ₆ H ₃ MgBr	C ₆ H ₅ [2,3-(CH ₃) ₂ C ₆ H ₃]CHOH (44%)	124
C ₆ H ₅ CHO	3,5-(CH ₃) ₂ C ₆ H ₃ MgBr	C ₆ H ₅ [3,5-(CH ₃) ₂ C ₆ H ₃]CHOH (50%)	124
C ₆ H ₅ CHO	(CH ₂) ₅ N(CH ₂) ₃ MgCl	C ₆ H ₅ [(CH ₂) ₅ N(CH ₂) ₃]CHOH (63%)	224
C ₆ H ₅ CHO	(CH ₂) ₅ N(CH ₂) ₃ Cl + Mg	C ₆ H ₅ [(CH ₂) ₅ N(CH ₂) ₃]CHOH	233
C ₆ H ₅ CHO	1-Indenyl-MgBr	Phenyl-1-indenylmethanol	60
C ₆ H ₅ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₅ MgCl	(C ₂ H ₅) ₂ N(CH ₂) ₅ CH(C ₆ H ₅)OH	224
C ₆ H ₅ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₅ Cl + Mg	(C ₂ H ₅) ₂ N(CH ₂) ₅ CH(C ₆ H ₅)OH	233
C ₆ H ₅ CHO	(CH ₃) ₅ C ₆ Br + C ₂ H ₅ Br + Mg	(CH ₃) ₅ C ₆ H; "bis(pentamethylbenzhydrol)"	296
C ₆ H ₅ CHO	(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₃ MgCl	(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₃ CH(C ₆ H ₅)OH (69%)	224
C ₆ H ₅ CHO	(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₃ Cl + Mg	(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₃ CH(C ₆ H ₅)OH	233
C ₆ H ₅ CHO (16 g.)	2-C ₆ H ₅ C ₆ H ₄ MgI (4 g. Mg)	C ₆ H ₅ (2-C ₆ H ₅ C ₆ H ₄)CHOH (21 g.)	183
C ₆ H ₅ CHO (2 ⁺ equiv.)	2-C ₆ H ₅ C ₆ H ₄ MgI	2-C ₆ H ₅ C ₆ H ₄ COC ₆ H ₅ (69.5%)	37
C ₆ H ₅ CHO	9-Phenanthryl-MgBr	Phenyl-9-phenanthrylmethanol (72%)	11

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₆O (<i>cont.</i>)			
C ₆ H ₅ CHO	(C ₆ H ₅) ₃ CMgCl	C ₆ H ₅ [(C ₆ H ₅) ₃ C]CHOH; C ₆ H ₅ CH(OH)C ₆ H ₄ -4-CH(C ₆ H ₅) ₂ (proportions depending on expt'l conditions.)	298,*324
C ₆ H ₅ CHO (1.6 g.)	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)MgBr (5.0 g. C ₂₀ H ₁₅ Br)	C ₆ H ₅ [(C ₆ H ₅) ₂ C=C(C ₆ H ₅)]CHOH	.182
C ₆ H ₅ CHO	2,4,6-(C ₆ H ₅) ₃ C ₆ H ₂ MgBr (excess †)	C ₆ H ₅ [2,4,6-(C ₆ H ₅) ₃ C ₆ H ₂]CHOH	186
C₇H₆O₂			
2-HOC ₆ H ₄ CHO	1-Indenyl-MgBr (2 equiv.)	2-Hydroxyphenyl-1-indenylmethanol (62%)	60
3-HOC ₆ H ₄ CHO	<i>n</i> -C ₅ H ₁₁ MgI	<i>n</i> -C ₅ H ₁₁ (3-HOC ₆ H ₄)CHOH (97%)	228
4-HOC ₆ H ₄ CHO	C ₆ H ₅ CH(CO ₂ Na)MgCl ‡	4-HOC ₆ H ₄ CH(OH)CH(C ₆ H ₅)CO ₂ H (15.5%); 4-HOC ₆ H ₄ CH=CHC ₆ H ₅ (29.6%)	158
C₇H₁₁OBr			
2-Bromocyclohexanecarboxaldehyde	CH ₃ MgI	CH ₃ COCH(CH ₂) ₅	315
2-Bromocyclohexanecarboxaldehyde	C ₂ H ₅ MgBr	C ₂ H ₅ COCH(CH ₂) ₅	315
2-Bromocyclohexanecarboxaldehyde	C ₆ H ₅ MgBr	2-Phenylcyclohexanecarboxaldehyde §	315
C₇H₁₂O			
(CH ₂) ₅ CHCHO	C ₆ H ₅ CH ₂ MgCl	(CH ₂) ₅ CH(C ₆ H ₅ CH ₂)CHOH (76%)	339

* Earlier references are listed by Schmidlin and Garcia-Banús (298).

† To avoid benzaldehyde oxidation of product to ketone.

‡ In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

§ Due to rearrangement of (and elimination from) initially formed unstable halohydrin.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₃OBr			
<i>n</i> -C ₅ H ₁₁ CHBrCHO	CH ₃ MgI	CH ₃ (<i>n</i> -C ₅ H ₁₁ CHBr)CHOH ("poor yield"); CH ₃ CO- <i>n</i> -C ₆ H ₁₃ ; <i>n</i> -C ₆ H ₁₃ (CH ₃) ₂ COH; C ₉ H ₁₈	174
C₇H₁₄O			
<i>n</i> -C ₆ H ₁₃ CHO	$\dagger \equiv \text{CMgBr}$ ₂	$[\equiv \text{CCH(OH)-}n\text{-C}_6\text{H}_{13}]_2$	81
<i>n</i> -C ₆ H ₁₃ CHO	$(\equiv \text{CMgI})_2$	$[\equiv \text{CCH(OH)-}n\text{-C}_6\text{H}_{13}]_2$; HC \equiv C(<i>n</i> -C ₆ H ₁₃)CHOH	155
<i>n</i> -C ₆ H ₁₃ CHO	C ₂ H ₅ MgBr	C ₂ H ₅ (<i>n</i> -C ₆ H ₁₃)CHOH (60-85%)*	326,375
<i>n</i> -C ₆ H ₁₃ CHO	H ₂ C = CHCH ₂ Br + Mg	H ₂ C = CHCH ₂ (<i>n</i> -C ₆ H ₁₃)CHOH (48%)	165
<i>n</i> -C ₆ H ₁₃ CHO	<i>n</i> -C ₃ H ₇ MgCl	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₆ H ₁₃)CHOH (74%)	169
<i>n</i> -C ₆ H ₁₃ CHO (8.0 moles)	<i>i</i> -C ₃ H ₇ MgBr (8.8 moles C ₃ H ₇ Br)	<i>i</i> -C ₃ H ₇ (<i>n</i> -C ₆ H ₁₃)CHOH (66%)	43,269
<i>n</i> -C ₆ H ₁₃ CHO	<i>n</i> -C ₄ H ₉ MgX	<i>n</i> -C ₄ H ₉ (<i>n</i> -C ₆ H ₁₃)CHOH	104
<i>n</i> -C ₆ H ₁₃ CHO (280 g.)	<i>n</i> -C ₄ H ₉ MgI (458 g. C ₄ H ₉ I)	<i>n</i> -C ₄ H ₉ (<i>n</i> -C ₆ H ₁₃)CHOH (110 g.)	42
<i>n</i> -C ₆ H ₁₃ CHO	(CH ₂) ₄ CHMgBr	(CH ₂) ₄ CH(<i>n</i> -C ₆ H ₁₃)CHOH (11%)	85
<i>n</i> -C ₆ H ₁₃ CHO	<i>n</i> -C ₅ H ₁₁ MgX	<i>n</i> -C ₅ H ₁₁ (<i>n</i> -C ₆ H ₁₃)CHOH	104
<i>n</i> -C ₆ H ₁₃ CHO (100 g.)	<i>i</i> -C ₅ H ₁₁ MgBr (180 g. C ₅ H ₁₁ Br)	<i>i</i> -C ₅ H ₁₁ (<i>n</i> -C ₆ H ₁₃)CHOH (102 g.)	269
<i>n</i> -C ₆ H ₁₃ CHO	C ₆ H ₅ MgBr	C ₆ H ₅ (<i>n</i> -C ₆ H ₁₃)CHOH	54
<i>n</i> -C ₆ H ₁₃ CHO	<i>n</i> -C ₆ H ₁₃ MgX	(<i>n</i> -C ₆ H ₁₃) ₂ CHOH	104
<i>n</i> -C ₆ H ₁₃ CHO (<i>ca.</i> 0.3 mole)	C ₆ H ₅ CH ₂ MgCl (<i>ca.</i> 0.4 mole)	<i>n</i> -C ₆ H ₁₃ (C ₆ H ₅ CH ₂)CHOH (55%); 2- <i>n</i> -C ₆ H ₁₃ CH(OH)C ₆ H ₄ CH ₂ CH(OH)- <i>n</i> -C ₆ H ₁₃ (14%)	454
<i>n</i> -C ₆ H ₁₃ CHO	<i>n</i> -C ₇ H ₁₅ MgX	<i>n</i> -C ₆ H ₁₃ (<i>n</i> -C ₇ H ₁₅)CHOH	104
<i>n</i> -C ₆ H ₁₃ CHO	C ₆ H ₅ C \equiv CMgBr	<i>n</i> -C ₆ H ₁₃ (C ₆ H ₅ C \equiv C)CHOH (75%)	214
<i>n</i> -C ₆ H ₁₃ CHO	C ₆ H ₅ CH(CO ₂ Na)MgCl \dagger	<i>n</i> -C ₆ H ₁₃ CH(OH)CH(C ₆ H ₅)CO ₂ H	158

* Tuot (326) reports the yields for a series of preparations as ranging from 60% to 85%.

\dagger In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₄O (<i>cont.</i>)			
<i>n</i> -C ₆ H ₁₃ CHO	C ₆ H ₅ (CH ₂) ₂ CH(CH ₃)CH ₂ MgBr	<i>n</i> -C ₆ H ₁₃ [C ₆ H ₅ (CH ₂) ₂ CH(CH ₃)CH ₂]CHOH	202
<i>n</i> -C ₆ H ₁₃ CHO	2-C ₆ H ₅ C ₆ H ₄ MgI	<i>n</i> -C ₆ H ₁₃ (2-C ₆ H ₅ C ₆ H ₄)CHOH (> 50%)*	38
C₇H₁₅ON			
(CH ₃) ₂ NCH ₂ (CH ₃) ₂ CCHO	C ₂ H ₅ MgI (2 equiv.)	C ₂ H ₅ [(CH ₃) ₂ NCH ₂ (CH ₃) ₂ C]CHOH ("good yield")†	226
(CH ₃) ₂ NCH ₂ (CH ₃) ₂ CCHO	<i>n</i> -C ₄ H ₉ MgBr (2 equiv.)	<i>n</i> -C ₄ H ₉ [(CH ₃) ₂ NCH ₂ (CH ₃) ₂ C]CHOH ("good yield")†	226
(CH ₃) ₂ NCH ₂ (CH ₃) ₂ CCHO	C ₆ H ₅ MgBr (2 equiv.)	C ₆ H ₅ [(CH ₃) ₂ NCH ₂ (CH ₃) ₂ C]CHOH ("good yield")†	226
C₈H₆O₂			
C ₆ H ₄ -1,2-(CHO) ₂ (100 g.)	RMgBr† (100 g. Mg)	C ₆ H ₄ -1,2-(CHROH) ₂ †	74
C ₆ H ₄ -1,2-(CHO) ₂ (6.7 g.)	CH ₃ MgI (24.9 g. CH ₃ I)	C ₆ H ₄ -1,2-[CH(OH)CH ₃] ₂	246
C ₆ H ₄ -1,2-(CHO) ₂	C ₂ H ₅ MgI (3.5 equiv.)	C ₆ H ₄ -1,2-[CH(OH)C ₂ H ₅] ₂	246
C ₆ H ₄ -1,2-(CHO) ₂	C ₆ H ₅ MgI	1,3-Diphenylphthalan	246
C ₆ H ₄ -1,3-(CHO) ₂ (100 g.)	RMgBr† (100 g. Mg)	C ₆ H ₄ -1,3-(CHROH) ₂ †	74
C ₆ H ₄ -1,3-(CHO) ₂ (50 g., 0.37 mole)	CH ₃ MgI (313 g., 2.1 moles CH ₃ I)	C ₆ H ₄ -1,3-[CH(OH)CH ₃] ₂ (25 g., 40%, crude)	163
C ₆ H ₄ -1,4-(CHO) ₂ (100 g.)	RMgBr† (100 g. Mg)	C ₆ H ₄ -1,4-(CHROH) ₂ †	74
C ₆ H ₅ COCHO	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ C(OH)CH(C ₆ H ₅)OH (4 g., crude)	212
"Dimeric crotonaldehyde"§	CH ₃ MgX (1.25 equiv.)	CH ₃ (C ₇ H ₁₁ O)CHOH (> 50%)	79

* Figure recorded represents overall yield of olefin obtained upon subsequent dehydration.

† Yields stated to be "good, in general," for series of reactions studied.

‡ R = CH₃, C₂H₅, C₆H₅.

§ Delepine (73) assigns to "dimeric crotonaldehyde" the constitution of 4,6-dimethyl-5-oxacyclohexene-1-carboxaldehyde.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₈H₆O₂ (cont.)			
"Dimeric crotonaldehyde"	C ₂ H ₅ MgI (1.25 equiv.)	C ₂ H ₅ (C ₇ H ₁₁ O)CHOH (> 50%)	79,73
"Dimeric crotonaldehyde"	<i>i</i> -C ₃ H ₇ MgX (1.25 equiv.)	<i>i</i> -C ₃ H ₇ (C ₇ H ₁₁ O)CHOH (> 50%)	79
"Dimeric crotonaldehyde"	<i>i</i> -C ₄ H ₉ MgX	<i>i</i> -C ₄ H ₉ (C ₇ H ₁₁ O)CHOH (> 50%)	79
"Dimeric crotonaldehyde"	<i>i</i> -C ₅ H ₁₁ MgX	<i>i</i> -C ₅ H ₁₁ (C ₇ H ₁₁ O)CHOH (> 50%)	79
C₈H₆O₂Cl₂			
2-CH ₃ O-3,5-Cl ₂ C ₆ H ₂ CHO (5.000 g.)	9-Phenanthryl-MgBr (0.645 g. C ₁₄ H ₉ Br)	2-CH ₃ O-3,5-Cl ₂ C ₆ H ₂ (9-C ₁₄ H ₉)CHOH (3.6 g., 37%)	314
C₈H₆O₃			
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	CH ₃ MgI	CH ₃ (3,4-CH ₂ O ₂ =C ₆ H ₃)CHOH; 3,4-CH ₂ O ₂ =C ₆ H ₃ CH=CH ₂ ; 3,4-CH ₂ O ₂ =C ₆ H ₃ COCH ₃ ; (3,4-CH ₂ O ₂ =C ₆ H ₃ CH=CH-) _x	216,176
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	C ₂ H ₅ MgI	C ₂ H ₅ (3,4-CH ₂ O ₂ =C ₆ H ₃)CHOH	216
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO (60.0 g.)	H ₂ C=CHCH ₂ Cl (65.0 g.) + Mg (17.0 g.)	H ₂ C=CHCH ₂ (3,4-CH ₂ O ₂ =C ₆ H ₃)CHOH (54.4 g.)	414
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	H ₂ C=CHCH ₂ Br + Mg	H ₂ C=CHCH ₂ (3,4-CH ₂ O ₂ =C ₆ H ₃)CHOH	188
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	<i>n</i> -C ₃ H ₇ MgI (2 equiv.)	<i>n</i> -C ₃ H ₇ (3,4-CH ₂ O ₂ =C ₆ H ₃)CHOH	217
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (3,4-CH ₂ O ₂ =C ₆ H ₃)CHOH	317
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	(CH ₃) ₂ N(CH ₂) ₃ MgCl	(CH ₃) ₂ N(CH ₂) ₃ (3,4-CH ₂ O ₂ =C ₆ H ₃)CHOH	224
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	(CH ₃) ₂ N(CH ₂) ₃ Cl + Mg	(CH ₃) ₂ N(CH ₂) ₃ (3,4-CH ₂ O ₂ =C ₆ H ₃)CHOH	233
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO (47.5 g.)	C ₆ H ₅ CH ₂ MgCl (40.0 g. C ₇ H ₇ Cl)	3,4-CH ₂ O ₂ =C ₆ H ₃ CH=CHC ₆ H ₅ (18 g.)	131
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	C ₆ H ₅ CH ₂ MgCl (2 equiv.)	C ₆ H ₅ CH ₂ (3,4-CH ₂ O ₂ =C ₆ H ₃)CHOH (90%)	317
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ MgCl	3,4-CH ₂ O ₂ =C ₆ H ₃ [(C ₂ H ₅) ₂ N(CH ₂) ₃]CHOH	224

* Delepine (73) assigns to "dimeric crotonaldehyde" the constitution of 4,6-dimethyl-5-oxacyclohexene-1-carboxaldehyde.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₆O₃ (cont.)			
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	3,4-CH ₂ O ₂ =C ₆ H ₃ [(C ₂ H ₅) ₂ N(CH ₂) ₃]CHOH	233
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	C ₆ H ₅ CH(CO ₂ Na)MgCl *	3,4-CH ₂ O ₂ =C ₆ H ₃ CH(OH)CH(C ₆ H ₅)CO ₂ H (23%)	158
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	(CH ₂) ₅ N(CH ₂) ₃ MgCl	3,4-CH ₂ O ₂ =C ₆ H ₃ [(CH ₂) ₅ N(CH ₂) ₃]CHOH	224
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	(CH ₂) ₅ N(CH ₂) ₃ Cl + Mg	3,4-CH ₂ O ₂ =C ₆ H ₃ [(CH ₂) ₂ N(CH ₂) ₃]CHOH	233
3,4-CH ₂ O ₂ =C ₆ H ₃ CHO	1-Indenyl-MgBr	3,4-Methylenedioxyphenyl- 1-indenylmethanol	60
C₈H₇O₃			
2-HO ₂ CC ₆ H ₄ CHO	CH ₃ MgI (4 equiv.)	3-Methylphthalide	302
2-HO ₂ CC ₆ H ₄ CHO	C ₂ H ₅ MgI (31.2 g. C ₂ H ₅ I)	3-Ethylphthalide (9 g.)	231
2-HO ₂ CC ₆ H ₄ CHO	C ₆ H ₅ MgI (4 equiv.)	3-Phenylphthalide	231
C₈H₈O			
C ₆ H ₅ CH ₂ CHO	2-ClC ₆ H ₄ MgI	2-ClC ₆ H ₄ (C ₆ H ₅ CH ₂)CHOH (70%)	25
C ₆ H ₅ CH ₂ CHO	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CH(C ₆ H ₅ CH ₂)CHOH (61%)	265
C ₆ H ₅ CH ₂ CHO (21.4 g.)	2-C ₆ H ₅ C ₆ H ₄ MgI (50.0 g. C ₁₂ H ₉ I)	C ₆ H ₅ CH ₂ (2-C ₆ H ₅ C ₆ H ₄)CHOH (9.5 g., 19%)	430
C ₆ H ₅ CH ₂ CHO (12.5 g.)	9-Phenanthryl-MgBr (25.7 ml. C ₁₄ H ₉ Br)	1-(9-Phenanthryl)-2-phenylethanol (16.0 g.)	22
4-CH ₃ C ₆ H ₄ CHO	(≡CMgBr) ₂	[≡CCH(OH)C ₆ H ₄ -4-CH ₃] ₂	421,422
4-CH ₃ C ₆ H ₄ CHO	C ₂ H ₅ I + Mg	C ₂ H ₅ (4-CH ₃ C ₆ H ₄)CHOH; (C ₈ H ₈ O) ₂ ; 4-CH ₃ C ₆ H ₄ CH ₂ OH	416
4-CH ₃ C ₆ H ₄ CHO	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (4-CH ₃ C ₆ H ₄)CHOH (41%)	377
C₈H₈O₂			
2-CH ₃ OC ₆ H ₄ CHO	CH ₃ MgI	CH ₃ (2-CH ₃ OC ₆ H ₄)CHOH (80%)	176,222,275, 307

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₈H₈O₂ (cont.)			
2-CH ₃ OC ₆ H ₄ CHO	CH ₃ MgBr	CH ₃ (2-CH ₃ OC ₆ H ₄)CHOH	130
2-CH ₃ OC ₆ H ₄ CHO	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (2-CH ₃ OC ₆ H ₄)CHOH (93-94%)	209
2-CH ₃ OC ₆ H ₄ CHO	C ₆ H ₅ MgX*	C ₆ H ₅ (2-CH ₃ OC ₆ H ₄)CHOH (95-97%)	310
2-CH ₃ OC ₆ H ₄ CHO	C ₆ H ₅ CH(CO ₂ Na)MgCl [†]	2-CH ₃ OC ₆ H ₄ CH(OH)CH(C ₆ H ₅)CO ₂ H (95.8%)	158
3-CH ₃ OC ₆ H ₄ CHO	CH ₃ MgI (excess)	CH ₃ (3-CH ₃ OC ₆ H ₄)CHOH	176,307
3-CH ₃ OC ₆ H ₄ CHO	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (3-CH ₃ OC ₆ H ₄)CHOH (93-94%)	209
3-CH ₃ OC ₆ H ₄ CHO	<i>n</i> -C ₄ H ₉ MgCl	<i>n</i> -C ₄ H ₉ (3-CH ₃ OC ₆ H ₄)CHOH (92%, crude)	4
4-CH ₃ OC ₆ H ₄ CHO	CH ₃ MgBr (excess)	CH ₃ (4-CH ₃ OC ₆ H ₄)CHOH	130
4-CH ₃ OC ₆ H ₄ CHO	CH ₃ MgI (excess)	CH ₃ (4-CH ₃ OC ₆ H ₄)CHOH	176,307
4-CH ₃ OC ₆ H ₄ CHO	(≡CMgBr) ₂	[≡CCH(OH)C ₆ H ₄ -4-OCH ₃] ₂	421,422
4-CH ₃ OC ₆ H ₄ CHO	(≡CMgI) ₂	[≡CCH(OH)C ₆ H ₄ -4-OCH ₃] ₂	155
4-CH ₃ OC ₆ H ₄ CHO	C ₂ H ₅ MgX*	C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)CHOH; 4-CH ₃ OC ₆ H ₄ CH=CHCH ₃	129
4-CH ₃ OC ₆ H ₄ CHO	C ₂ H ₅ MgBr	4-CH ₃ OC ₆ H ₄ CH=CHCH ₃ ; (4-CH ₃ OC ₆ H ₄ CH=CHCH ₃) ₂	366
4-CH ₃ OC ₆ H ₄ CHO	C ₂ H ₅ MgI	C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)CHOH	293
4-CH ₃ OC ₆ H ₄ CHO	<i>s</i> -C ₄ H ₉ MgBr (1.5 equiv.)	<i>s</i> -C ₄ H ₉ (4-CH ₃ OC ₆ H ₄)CHOH	348
4-CH ₃ OC ₆ H ₄ CHO	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₅ H ₁₁ (4-CH ₃ OC ₆ H ₄)CHOH	63
4-CH ₃ OC ₆ H ₄ CHO	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ (4-CH ₃ OC ₆ H ₄)CHOH	234
4-CH ₃ OC ₆ H ₄ CHO	4-ClC ₆ H ₄ MgI	4-ClC ₆ H ₄ (4-CH ₃ OC ₆ H ₄)CHOH	234
4-CH ₃ OC ₆ H ₄ CHO (28 g.)	C ₆ H ₅ MgBr (40 g. C ₆ H ₅ Br)	C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)CHOH (40 g., 90%)	10; <i>c.f.</i> 187
4-CH ₃ OC ₆ H ₄ CHO	(CH ₂) ₅ CHMgBr	(CH ₂) ₅ CH(4-CH ₃ OC ₆ H ₄)CHOH	300
4-CH ₃ OC ₆ H ₄ CHO	3-CH ₃ C ₆ H ₄ MgBr	3-CH ₃ C ₆ H ₄ (4-CH ₃ OC ₆ H ₄)CHOH (55%)	13
4-CH ₃ OC ₆ H ₄ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ MgCl	(C ₂ H ₅) ₂ N(CH ₂) ₃ (4-CH ₃ OC ₆ H ₄)CHOH	224
4-CH ₃ OC ₆ H ₄ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	(C ₂ H ₅) ₂ N(CH ₂) ₃ (4-CH ₃ OC ₆ H ₄)CHOH	233,304

* X = Br, I.

[†]In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₈O₂ (cont.)			
4-CH ₃ OC ₆ H ₄ CHO	C ₆ H ₅ CH(CO ₂ Na)MgCl*	4-CH ₃ OC ₆ H ₄ CH(OH)CH(C ₆ H ₅)CO ₂ H (95.8%)	158
4-CH ₃ OC ₆ H ₄ CHO	(CH ₂) ₅ N(CH ₂) ₃ MgCl	4-CH ₃ OC ₆ H ₄ [(CH ₂) ₅ N(CH ₂) ₃]CHOH (74%)	224
4-CH ₃ OC ₆ H ₄ CHO	(CH ₂) ₅ N(CH ₂) ₃ Cl + Mg	4-CH ₃ OC ₆ H ₄ [(CH ₂) ₅ N(CH ₂) ₃]CHOH	233
4-CH ₃ OC ₆ H ₄ CHO	1-Indenyl-MgBr	Anisyl-1-indenylmethanol (75%)	60
4-CH ₃ OC ₆ H ₄ CHO	1-C ₁₀ H ₇ MgBr	4-CH ₃ OC ₆ H ₄ (1-C ₁₀ H ₇)CHOH (74%)	301
C₈H₈O₃			
2-CH ₃ O-3-HOC ₆ H ₃ CHO	C ₂ H ₅ MgBr	2-CH ₃ O-3-HOC ₆ H ₃ CH=CHCH ₃ (20%)	78
2-CH ₃ O-3-HOC ₆ H ₃ CHO	C ₂ H ₅ MgI	C ₂ H ₅ (2-CH ₃ O-3-HOC ₆ H ₃)CHOH (90%); 2-CH ₃ O-3-HOC ₆ H ₃ CH=CHCH ₃ (10%) (Total yield not stated)	78
3-CH ₃ O-4-HOC ₆ H ₃ CHO	C ₆ H ₅ CH(CO ₂ Na)MgCl*	3-CH ₃ O-4-HOC ₆ H ₃ CH(OH)CH(C ₆ H ₅)CO ₂ H (22%); 3-CH ₃ O-4-HOC ₆ H ₃ CH=CHC ₆ H ₅	158
C₈H₁₀O			
CH ₃ (CH=CH) ₃ CHO (31 g.)	(≡CMgBr) ₂ (6 g. Mg)	[≡CCH(OH)(CH=CH) ₃ CH ₃] ₂ (7 g.)	400
CH ₃ (CH=CH) ₃ CHO (12 g.)	1-Cyclohexenylethynyl-MgBr (10 g. C ₈ H ₁₀)	1-(1-Cyclohexenyl)deca-4,6,8-trien-1-yn- 3-ol (6.1 g.)	126
Δ ^{4,6} -Dihydro- <i>o</i> -tolualdehyde (50 g.)	CH ₃ MgI (71 g. CH ₃ I)	1-CH ₃ -2-C ₂ H ₅ C ₆ H ₄ (71%, crude)	123
Δ ^{4,6} -Dihydro- <i>o</i> -tolualdehyde	C ₂ H ₅ MgI	1-CH ₃ -2- <i>n</i> -C ₃ H ₇ C ₆ H ₄ (68%, crude)	123
C₈H₁₆O			
<i>n</i> -C ₇ H ₁₅ CHO	CH ₃ MgI	CH ₃ (<i>n</i> -C ₇ H ₁₅)CHOH	375
<i>n</i> -C ₇ H ₁₅ CHO	HC≡CH + 2 C ₂ H ₅ MgBr	[≡CCH(OH)- <i>n</i> -C ₇ H ₁₅] ₂ (42%)	268

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₈H₁₆O (<i>cont.</i>)			
<i>n</i> -C ₇ H ₁₅ CHO	<i>n</i> -C ₈ H ₁₇ MgCl	<i>n</i> -C ₇ H ₁₅ (<i>n</i> -C ₈ H ₁₇)CHOH (67%)	8
C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CHCHO (<i>ca.</i> 0.3 mole)	C ₆ H ₅ CH ₂ MgCl (<i>ca.</i> 0.4 mole)	C ₆ H ₅ CH ₂ [C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CH]CHOH (66%); 2-C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CHCH(OH)— C ₆ H ₄ CH ₂ CH(OH)CH(C ₂ H ₅)- <i>n</i> -C ₄ H ₉ (6%)	454
C₉H₆O			
C ₆ H ₅ C≡CCHO (13 g.)	CH ₃ MgI	CH ₃ (C ₆ H ₅ C≡C)CHOH (7.5 g.); recovered aldehyde (<i>ca.</i> 1.0 g.)	36
C ₆ H ₅ C≡CCHO (13 g.)	C ₂ H ₅ MgBr	C ₂ H ₅ (C ₆ H ₅ C≡C)CHOH (9.5 g.)	36
C ₆ H ₅ C≡CCHO (13 g.)	<i>n</i> -C ₃ H ₇ MgI	<i>n</i> -C ₃ H ₇ (C ₆ H ₅ C≡C)CHOH (7.5 g.)	36
C ₆ H ₅ C≡CCHO (13 g.)	<i>i</i> -C ₄ H ₉ MgI	<i>i</i> -C ₄ H ₉ (C ₆ H ₅ C≡C)CHOH (5.5 g.)	36
C ₆ H ₅ C≡CCHO (13 g.)	C ₆ H ₅ MgBr	C ₆ H ₅ (C ₆ H ₅ C≡C)CHOH (7.0 g.)	36
C₉H₇OBr			
C ₆ H ₅ CH=CBrCHO	CH ₃ MgI	CH ₃ (C ₆ H ₅ CH=CBr)CHOH	295
C ₆ H ₅ CH=CBrCHO	C ₆ H ₅ MgBr	C ₆ H ₅ (C ₆ H ₅ CH=CBr)CHOH	184
C₉H₈O			
C ₆ H ₅ CH=CHCHO	CH ₃ MgBr	CH ₃ (C ₆ H ₅ CH=CH)CHOH	243,178
C ₆ H ₅ CH=CHCHO (26 g.)	CH ₃ MgI (32 g. CH ₃ I)	CH ₃ (C ₆ H ₅ CH=CH)CHOH (18 g.)	380,40,61, 295
C ₆ H ₅ CH=CHCHO	CH ₃ MgI (0.5 equiv.)	CH ₃ COCH=CHC ₆ H ₅ ; C ₆ H ₅ CH=CHCH ₂ OH; C ₆ H ₅ CH=CHCO ₂ H; recovered aldehyde	219
C ₆ H ₅ CH=CHCHO	(≡MgBr) ₂	[≡CCH(OH)CH=CHC ₆ H ₅] ₂	149,81
C ₆ H ₅ CH=CHCHO (30 g.)	C ₂ H ₅ MgBr (33 g. C ₂ H ₅ Br)	C ₂ H ₅ (C ₆ H ₅ CH=CH)CHOH (24.5 g.)	173,138,229
C ₆ H ₅ CH=CHCHO	C ₂ H ₅ MgI (0.5 equiv.)	C ₂ H ₅ COCH=CHC ₆ H ₅ ; C ₆ H ₅ CH=CHCH ₂ OH	219
C ₆ H ₅ CH=CHCHO (32 g.)	<i>n</i> -C ₄ H ₉ MgBr (67 g. C ₄ H ₉ Br)	<i>n</i> -C ₄ H ₉ (C ₆ H ₅ CH=CH)CHOH (17 g.); C ₆ H ₅ CH=CHCH ₂ OH (5 g.)	267

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₈O (<i>cont.</i>)			
C ₆ H ₅ CH=CHCHO (9.5 g.)	<i>i</i> -C ₄ H ₉ MgCl (8.5 g. C ₄ H ₉ Cl)	Recovered aldehyde (30%)	229
C ₆ H ₅ CH=CHCHO (9.5 g.)	<i>i</i> -C ₄ H ₉ MgBr (13.7 g. C ₄ H ₉ Br)	Recovered aldehyde (12%); <i>i</i> -C ₄ H ₉ (C ₆ H ₅ CH=CH)CHOH ("in satisfactory yield and purity"); <i>no</i> C ₆ H ₅ CH=CHCH ₂ OH	229,138
C ₆ H ₅ CH=CHCHO (64 g., 0.485 mole)	<i>t</i> -C ₅ H ₁₁ MgCl (0.79 mole)	<i>t</i> -C ₅ H ₁₁ (C ₆ H ₅)CHCH ₂ CHO; <i>no</i> C ₆ H ₅ CH=CHCH ₂ OH	358
C ₆ H ₅ CH=CHCHO	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ (C ₆ H ₅ CH=CH)CHOH (m.p., 100°); unidentified oil	360
C ₆ H ₅ CH=CHCHO (33 g.)	4-ClC ₆ H ₄ MgI (60 g. C ₆ H ₄ ClI)	4-ClC ₆ H ₄ (C ₆ H ₅ CH=CH)CHOH; C ₆ H ₅ (4-ClC ₆ H ₄ CH=CH)CHOH (total yield, 54 g., crude)	41
C ₆ H ₅ CH=CHCHO (25 g.)	C ₆ H ₅ MgBr (47 g. C ₆ H ₅ Br)	C ₆ H ₅ (C ₆ H ₅ CH=CH)CHOH (21 g.)	252,200
C ₆ H ₅ CH=CHCHO	C ₆ H ₅ MgBr	<i>trans</i> -C ₆ H ₅ (C ₆ H ₅ CH=CH)CHOH (63%)	44,184
C ₆ H ₅ CH=CHCHO (33 g.)	4-CH ₃ C ₆ H ₄ MgBr (43 g. C ₇ H ₇ Br)	4-CH ₃ C ₆ H ₄ (C ₆ H ₅ CH=CH)CHOH (22 g.)	41
C ₆ H ₅ CH=CHCHO	4-CH ₃ OC ₆ H ₄ MgBr	4-CH ₃ OC ₆ H ₄ (C ₆ H ₅ CH=CH)CHOH (m.p., 106–107°) (16%); <i>no</i> sat'd aldehyde (1,4-addition) detected	360
C ₆ H ₅ CH=CHCHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	(C ₂ H ₅) ₂ N(CH ₂) ₃ CH(OH)CH=CHC ₆ H ₅	233
C ₆ H ₅ CH=CHCHO	C ₆ H ₅ CH(CO ₂ Na)MgCl*	C ₆ H ₅ CH=CH ₂ CH(OH)CH(C ₆ H ₅)CO ₂ H (75%)	158
C₉H₁₀O			
CH ₃ (C ₆ H ₅)CHCHO	<i>t</i> -C ₄ H ₉ MgCl	<i>t</i> -C ₄ H ₉ [CH ₃ (C ₆ H ₅)CH]CHOH; CH ₃ (C ₆ H ₅)CHCH ₂ OH	381

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135–54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₉H₁₀O (<i>cont.</i>)			
CH ₃ (C ₆ H ₅)CHCHO	C ₆ H ₅ MgBr	C ₆ H ₅ [CH ₃ (C ₆ H ₅)CH]CHOH, α form (65%)	433,170,316
C ₆ H ₅ (CH ₂) ₂ CHO	CH ₃ MgI	CH ₃ (C ₆ H ₅ CH ₂ CH ₂)CHOH	31
3,5-(CH ₃) ₂ C ₆ H ₃ CHO (320 g., 2.83 moles)	CH ₃ MgI	CH ₃ [3,5-(CH ₃) ₂ C ₆ H ₃]CHOH (338.5 g., 80%)	223
C₉H₁₀O₂			
4-C ₂ H ₅ OC ₆ H ₄ CHO (60 g.)	C ₂ H ₅ MgI (125 g. C ₂ H ₅ I)	4-C ₂ H ₅ OC ₆ H ₄ CH=CHCH ₃ (32 g.); higher-boiling products	21
C₉H₁₀O₃			
2,3-(CH ₃ O) ₂ C ₆ H ₃ CHO	CH ₃ MgI	CH ₃ [2,3-(CH ₃ O) ₂ C ₆ H ₃]CHOH (93%)	263
2,3-(CH ₃ O) ₂ C ₆ H ₃ CHO	C ₂ H ₅ MgBr	C ₂ H ₅ [2,3-(CH ₃ O) ₂ C ₆ H ₃]CHOH	78
2,3-(CH ₃ O) ₂ C ₆ H ₃ CHO (24.9 g.)	C ₆ H ₅ MgBr (15.7 g. C ₆ H ₅ Br)	C ₆ H ₅ [2,3-(CH ₃ O) ₂ C ₆ H ₃]CHOH	17
2,3-(CH ₃ O) ₂ C ₆ H ₃ CHO (16.6 g.)	4-CH ₃ OC ₆ H ₄ MgBr (12.5 g. C ₇ H ₇ BrO)	4-CH ₃ OC ₆ H ₄ [2,3-(CH ₃ O) ₂ C ₆ H ₃]CHOH	17
3,4-(CH ₃ O) ₂ C ₆ H ₃ CHO (400 g., 2.41 moles)	CH ₃ MgI (344 g., 2.42 moles CH ₃ I)	3,4-(CH ₃ O) ₂ C ₆ H ₃ CH=CH ₂ (281 g., 18%)	434
3,4-(CH ₃ O) ₂ C ₆ H ₃ CHO (33 g.)	C ₂ H ₅ MgBr	C ₂ H ₅ [3,4-(CH ₃ O) ₂ C ₆ H ₃]CHOH (16 g.); recovered aldehyde (10 g.)	21
3,4-(CH ₃ O) ₂ C ₆ H ₃ CHO (66.4 g.)	H ₂ C=CHCH ₂ Cl (64.8 g.) + Mg (17.0 g.)	H ₂ C=CHCH ₂ [3,4-(CH ₃ O) ₂ C ₆ H ₃]CHOH (72.7 g., 87%)	414
3,4-(CH ₃ O) ₂ C ₆ H ₃ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ MgCl	(C ₂ H ₅) ₂ N(CH ₂) ₃ [3,4-(CH ₃ O) ₂ C ₆ H ₃]CHOH (10-15%)	224
3,4-(CH ₃ O) ₂ C ₆ H ₃ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	(C ₂ H ₅) ₂ N(CH ₂) ₃ [3,4-(CH ₃ O) ₂ C ₆ H ₃]CHOH	233
C₉H₁₁ON			
4-(CH ₃) ₂ NC ₆ H ₄ CHO	CH ₃ MgI	CH ₃ [4-(CH ₃) ₂ NC ₆ H ₄]CHOH (75%)	291
4-(CH ₃) ₂ NC ₆ H ₄ CHO	C ₂ H ₅ MgBr	C ₂ H ₅ [4-(CH ₃) ₂ NC ₆ H ₄]CHOH (74%)	291
4-(CH ₃) ₂ NC ₆ H ₄ CHO	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ [4-(CH ₃) ₂ NC ₆ H ₄]CHOH	234
4-(CH ₃) ₂ NC ₆ H ₄ CHO	4-ClC ₆ H ₄ MgBr	4-ClC ₆ H ₄ [4-(CH ₃) ₂ NC ₆ H ₄]CHOH	234

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₉H₁₁ON (<i>cont.</i>)			
4-(CH ₃) ₂ NC ₆ H ₄ CHO	C ₆ H ₅ MgBr	C ₆ H ₅ [4-(CH ₃) ₂ NC ₆ H ₄]CHOH	292
4-(CH ₃) ₂ NC ₆ H ₄ CHO	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ [4-(CH ₃) ₂ NC ₆ H ₄]CHOH (86%)	291
4-(CH ₃) ₂ NC ₆ H ₄ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	(C ₂ H ₅) ₂ N(CH ₂) ₃ [4-(CH ₃) ₂ NC ₆ H ₄]CHOH	233
4-(CH ₃) ₂ NC ₆ H ₄ CHO	1-C ₁₀ H ₇ MgBr	1-C ₁₀ H ₇ [4-(CH ₃) ₂ NC ₆ H ₄]CHOH (90%, crude)	291
C₉H₁₆O			
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CHO	CH ₃ MgI	CH ₃ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)]CHOH (60%)	77
C₉H₁₉ON			
(C ₂ H ₅) ₂ NCH ₂ (CH ₃) ₂ CCHO	C ₆ H ₅ MgBr (2 equiv.)	C ₆ H ₅ [(C ₂ H ₅) ₂ NCH ₂ (CH ₃) ₂ C]CHOH ("good yield")*	226
(C ₂ H ₅) ₂ NCH ₂ (CH ₃) ₂ CCHO (23.6 g., 0.15 mole)	4-CH ₃ OC ₁₀ H ₆ -1-MgBr (47.4 g., 0.2 mole C ₁₁ H ₉ BrO)	(C ₂ H ₅) ₂ NCH ₂ (CH ₃) ₂ C(4-CH ₃ O-1-C ₁₀ H ₆)CHOH (37.8 g., 72% crude hydrochloride)	161
C₁₀H₇ON			
Quinaldehyde †	CH ₃ MgI	1-α-Quinolylethanol	145
Quinaldehyde †	C ₂ H ₅ MgBr	1-α-Quinolyl-1-propanol	145
Quinaldehyde †	C ₆ H ₅ MgBr	Phenyl-α-quinolylmethanol (60%)	145
C₁₀H₁₀O			
C ₆ H ₅ CH=C(CH ₃)CHO	CH ₃ MgI	CH ₃ [C ₆ H ₅ CH=C(CH ₃)]CHOH	425
C₁₀H₁₀O₂			
C ₆ H ₅ COCH(CH ₃)CHO †	C ₂ H ₅ MgBr	C ₆ H ₅ COCH(CH ₃)CH(OH)C ₂ H ₅	407

* Yields stated to be "good, in general," for series of reactions studied.

† 2-Quinolinecarboxaldehyde.

* Yields recorded are reported by Reynolds (407) as those of C₆H₅COC(CH₃)=CHOH.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₁₀H₁₀O₂ (cont.)			
C ₆ H ₅ COCH(CH ₃)CHO*	C ₆ H ₅ MgBr	C ₆ H ₅ COC(CH ₃)=CHC ₆ H ₅	407
C₁₀H₁₀O₅			
2,5-(CH ₃ O) ₂ -3,4-CH ₂ O ₂ =C ₆ HCHO	CH ₃ MgI	CH ₃ [2,5-(CH ₃ O) ₂ -3,4-CH ₂ O ₂ =C ₆ H]CHOH [†]	88
2,5-(CH ₃ O) ₂ -3,4-CH ₂ O ₂ =C ₆ HCHO	C ₂ H ₅ MgI	C ₂ H ₅ [2,5-(CH ₃ O) ₂ -3,4-CH ₂ O ₂ =C ₆ H]CHOH [†]	88
2,5-(CH ₃ O) ₂ -3,4-CH ₂ O ₂ =C ₆ HCHO	C ₆ H ₅ MgI	C ₆ H ₅ [2,5-(CH ₃ O) ₂ -3,4-CH ₂ O ₂ =C ₆ H]CHOH [†]	88
2-HO ₂ C-3,4-(CH ₃ O) ₂ C ₆ H ₂ CHO	CH ₃ MgI (3 equiv.)	α-Methylmeconine [‡]	302
2-HO ₂ C-3,4-(CH ₃ O) ₂ C ₆ H ₂ CHO (7.8 g.)	C ₂ H ₅ MgI (23.4 g. C ₂ H ₅ I)	α-Ethylmeconine [§] (7.6 g., 96%)	230
2-HO ₂ C-3,4-(CH ₃ O) ₂ C ₆ H ₂ CHO (7.8 g.)	n-C ₃ H ₇ MgI (25.4 g. C ₃ H ₇ I)	α-n-Propylmeconine [¶] (6.5 g., 70%)	230
2-HO ₂ C-3,4-(CH ₃ O) ₂ C ₆ H ₂ CHO (5.2 g.)	C ₆ H ₅ MgI (20.4 g. C ₆ H ₅ I)	α-Phenylmeconine [‡]	230
C₁₀H₁₂O			
C ₂ H ₅ (C ₆ H ₅)CHCHO	C ₆ H ₅ MgBr	C ₆ H ₅ [C ₂ H ₅ (C ₆ H ₅)CH]CHOH, α form (55%)	433,170
C ₆ H ₅ (CH ₃) ₂ CCHO (32 g.)	C ₆ H ₅ MgBr (1.5 equiv.)	C ₆ H ₅ [C ₆ H ₅ (CH ₃) ₂ C]CHOH (16 g.)	207
i-C ₃ H ₇ C ₆ H ₄ CHO	(n-C ₄ H ₉) ₂ N(CH ₂) ₃ Cl + Mg	(n-C ₄ H ₉) ₂ N(CH ₂) ₃ (i-C ₃ H ₇ C ₆ H ₄)CHOH	233
2,4,6-(CH ₃) ₃ C ₆ H ₂ CHO (44.4 g.)	C ₆ H ₅ CH ₂ MgCl (49.2 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ [2,4,6-(CH ₃) ₃ C ₆ H ₂]CHOH (52.1 g., crude)	102

* The reactions recorded are reported by Reynolds (407) as those of C₆H₅COC(CH₃)=CHOH.

† A benzene-aldehyde suspension was added to the well-cooled Grignard reagent solution; inadequate cooling yields the corresponding ether.

‡ 3-Methyl-6,7-dimethoxyphthalide.

§ 3-Ethyl-6,7-dimethoxyphthalide.

¶ 3-n-Propyl-6,7-dimethoxyphthalide.

‡ 3-Phenyl-6,7-dimethoxyphthalide.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₂O (<i>cont.</i>)			
2,4,6-(CH ₃) ₃ C ₆ H ₂ CHO	2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂ MgCl	2,4,6-(CH ₃) ₃ C ₆ H ₂ [2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂]CHOH; [2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂ —] ₂	102
C₁₀H₁₂O₄			
3,4,5-(CH ₃ O) ₃ C ₆ H ₂ CHO	CH ₃ MgI	CH ₃ [3,4,5-(CH ₃ O) ₃ C ₆ H ₂]CHOH (65%)	227
3,4,5-(CH ₃ O) ₃ C ₆ H ₂ CHO	C ₂ H ₅ MgI	C ₂ H ₅ [3,4,5-(CH ₃ O) ₃ C ₆ H ₂]CHOH (60%)	227
C₁₀H₁₃O₃N			
2,4-Dimethyl-5-carbethoxy-3-pyrrolicarboxaldehyde	CH ₃ MgI	1-(2,4-Dimethyl-5-carbethoxy-3-pyrrolyl)ethanol (80%)	93
C₁₀H₁₆O			
(CH ₃) ₂ C=CH(CH ₂) ₂ C(CH ₃)=CHCHO	CH ₃ MgX	CH ₃ [(CH ₃) ₂ C=CH(CH ₂) ₂ C(CH ₃)=CH]CHOH	9
(CH ₃) ₂ C=CH(CH ₂) ₂ C(CH ₃)=CHCHO	C ₂ H ₅ MgX	C ₂ H ₅ [(CH ₃) ₂ C=CH(CH ₂) ₂ C(CH ₃)=CH]CHOH	9
(CH ₃) ₂ C=CH(CH ₂) ₂ C(CH ₃)=CHCHO	<i>i</i> -C ₄ H ₉ MgX	<i>i</i> -C ₄ H ₉ [(CH ₃) ₂ C=CH(CH ₂) ₂ C(CH ₃)=CH]CHOH	9
(CH ₃) ₂ C=CH(CH ₂) ₂ C(CH ₃)=CHCHO	C ₆ H ₅ MgX	C ₆ H ₅ [(CH ₃) ₂ C=CH(CH ₂) ₂ C(CH ₃)=CH]CHOH	9
(CH ₃) ₂ C=CH(CH ₂) ₂ C(CH ₃)=CHCHO (27.4 g.)	CH ₃ CH=C(CH ₃)C≡CMgBr (14.7 g. C ₆ H ₈)	(CH ₃) ₂ C=CH(CH ₂) ₂ C(CH ₃)=CH[CH ₃ CH=C(CH ₃)C≡C]CHOH (30.5 g.)	407
(CH ₃) ₂ C=CH(CH ₂) ₂ C(CH ₃)=CHCHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	(C ₂ H ₅) ₂ N(CH ₂) ₃ [(CH ₃) ₂ C=CH(CH ₂) ₂ C(CH ₃)=CH]CHOH	233
3-Camphenilancarboxaldehyde	C ₆ H ₅ MgBr	Phenyl-3-(2,2-dimethylnorcamphanyl)methanol	5
3-Camphenilancarboxaldehyde	C ₆ H ₅ CH ₂ MgCl	Benzyl-3-(2,2-dimethylnorcamphanyl)methanol	5

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₁₀H₁₆O (<i>cont.</i>)			
3-Camphenilancarboxaldehyde	1-C ₁₀ H ₇ MgBr	"Carbinol not isolable in pure form"	5
α -Campholenaldehyde*	CH ₃ MgI	1-(2,2,3-Trimethylcyclopent-3-enyl)propan-2-ol	282
α -Campholenaldehyde*	1-C ₁₀ H ₇ MgBr	"Carbinol not isolable in pure form"	5
C₁₀H₁₆O₃			
1,2,2-Trimethyl-3-carboxycyclopentane-1-carboxaldehyde	C ₂ H ₅ MgBr	β -Ethyl- β -campholide [†] (yield "poorer than for Me ester"; <i>i.e.</i> , <37%)	337
C₁₀H₁₈O			
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂ CHO	CH ₃ MgI	CH ₃ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂]CHOH (60%)	77,287
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂ CHO	CH ₃ MgBr	CH ₃ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂]CHOH (quant.)	285
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂ CHO	C ₂ H ₅ MgBr	C ₂ H ₅ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂]CHOH	285,121
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂ CHO	H ₂ C=CHCH ₂ Br + Mg	H ₂ C=CHCH ₂ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂]CHOH; (H ₂ C=CHCH ₂ -) ₂	285
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂ CHO	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂]CHOH (quant.)	285
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂ CHO	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂]CHOH	113
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂ CHO (35 g.)	(CH ₂) ₅ CHMgBr (50 g. C ₆ H ₁₁ Br)	(CH ₂) ₅ CH[(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂]CHOH (35-40 g.); (CH ₂) ₆ ; [(CH ₂) ₅ CH-] ₂	285

* 2,2,3-Trimethyl-3-cyclopentene-1-acetaldehyde.

[†] 4-Ethyl-5,8,8-trimethyl-3-oxabicyclo[3.2.1]octan-2-one.

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₁₀H₁₈O (cont.)			
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂ CHO (25 g.)	C ₆ H ₅ MgBr (31.4 g. C ₆ H ₅ Br)	C ₆ H ₅ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂]CHOH (25 g.)	285
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂ CHO	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂]CHOH (20%)*	285, 113
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂ CHO (52.0 g., 0.338 mole)	C ₆ H ₅ CH ₂ MgCl (0.663 mole C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂]CHOH (40.5 g.); C ₆ H ₅ CH ₂ OH; C ₆ H ₅ CH ₃ ; isopulegol †; 1-RCH ₂ (HO)CH-2-RCH ₂ (HO)CHCH ₂ C ₆ H ₄ ‡ (21.5 g. crude)	452
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂ CHO	C ₆ H ₅ C≡CMgBr	C ₆ H ₅ C≡C[(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂]CHOH	286
(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂ CHO	C ₆ H ₅ (CH ₂) ₂ MgBr	C ₆ H ₅ (CH ₂) ₂ [(CH ₃) ₂ C=CH(CH ₂) ₂ CH(CH ₃)CH ₂]CHOH (70%)	285
C₁₀H₁₈O₃			
H ₃ CO ₂ C(CH ₂) ₇ CHO (37.2 g.)	n-C ₄ H ₉ MgBr (27.4 g. C ₄ H ₉ Br)	n-C ₄ H ₉ [H ₃ CO ₂ C(CH ₂) ₇]CHOH (18.5 g., 38%)	250
H ₃ CO ₂ C(CH ₂) ₇ CHO (80 g.)	(CH ₂) ₅ CHMgBr	(CH ₂) ₅ CH[H ₃ CO ₂ C(CH ₂) ₇]CHOH (25 g., 23%)	426
H ₃ CO ₂ C(CH ₂) ₇ CHO	(CH ₂) ₅ CH(CH ₂) ₂ MgBr	(CH ₂) ₅ CH(CH ₂) ₂ [H ₃ CO ₂ C(CH ₂) ₇]CHOH (26%)	140
H ₃ CO ₂ C(CH ₂) ₇ CHO (30 g.)	n-C ₉ H ₁₉ MgBr (1 equiv.)	n-C ₉ H ₁₉ [H ₃ CO ₂ C(CH ₂) ₇]CHOH (17 g.)	322
C₁₀H₂₀O			
n-C ₉ H ₁₉ CHO	n-C ₆ H ₁₃ MgBr	n-C ₆ H ₁₃ (n-C ₉ H ₁₉)CHOH (70%)	8
n-C ₉ H ₁₉ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	n-C ₉ H ₁₉ [(C ₂ H ₅) ₂ N(CH ₂) ₃]CHOH	233

* Yield still poorer with C₆H₅CH₂MgBr.† Δ⁸(9)-p-Menthenol-3; 5-methyl-2-isopropenylcyclohexanol.‡ R = (CH₃)₂C=CH(CH₂)₂CH(CH₃)-.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₂₀O (<i>cont.</i>)			
<i>n</i> -C ₉ H ₁₉ CHO	(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₃ Cl + Mg	<i>n</i> -C ₉ H ₁₉ [(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₃]CHOH	233
C₁₁H₈O			
1-C ₁₀ H ₇ CHO (28.9 g.)	H ₂ C=CHCH ₂ Cl (27.4 ml.) + Mg (6.05 g.)	H ₂ C=CHCH ₂ (1-C ₁₀ H ₇)CHOH (31.3 g., 94%)	414,415
1-C ₁₀ H ₇ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ MgCl	1-C ₁₀ H ₇ [(C ₂ H ₅) ₂ N(CH ₂) ₃]CHOH	224
1-C ₁₀ H ₇ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	1-C ₁₀ H ₇ [(C ₂ H ₅) ₂ N(CH ₂) ₃]CHOH	233
2-C ₁₀ H ₇ CHO	C ₆ H ₅ MgBr	C ₆ H ₅ (2-C ₁₀ H ₇)CHOH (86%)	14
2-C ₁₀ H ₇ CHO (11 g.)	9-Phenanthryl-MgBr (18 g. C ₁₄ H ₉ Br)	[2-C ₁₀ H ₇ CH ₂ —] ₂	23
C₁₁H₉O₂N			
1-Methyl-2-oxo-1,2-dihydro- cinchoninaldehyde* (2.0 g., 0.01 mole)	C ₆ H ₅ MgBr (4.0 g. C ₆ H ₅ Br)	1-Methyl-4- α -hydroxybenzylcarbostyryl (0.9 g., 32%)	57
C₁₁H₁₂O₂			
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCHO (17.6 g.)	C ₆ H ₅ MgBr (31.4 g. C ₆ H ₅ Br)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCOC ₆ H ₅ (6.43 g.)	382
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCHO	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	[2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH(OH)—] ₂ ; [2,4,6-(CH ₃) ₃ C ₆ H ₂ CO—] ₂	382
C₁₁H₁₆ON₂			
2,4,-[(CH ₃) ₂ N] ₂ C ₆ H ₃ CHO	C ₂ H ₅ MgBr (3 equiv.)	C ₂ H ₅ {2,4,-[(CH ₃) ₂ N] ₂ C ₆ H ₃ }CHOH	383

* 1-Methyl-4-formyl-2(1*H*)-quinolinone.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₈O₃			
1,2,2-Trimethyl-3-carbomethoxy-cyclopentane-1-carboxaldehyde	CH ₃ MgI (4 equiv.)	β -Methyl- β -campholide* (62%); 1,2,2-trimethyl-1-(1-hydroxyethyl)-3-(2-hydroxy-2-propyl)cyclopentane; 1,2,4,4,8,8-hexamethyl-3-oxabicyclo[3.2.1]octane; 1,2,2-trimethyl-1-(1-hydroxyethyl)-3-isopropenyl-cyclopentane; 1,2,2-trimethyl-1-vinyl-3-isopropenylcyclopentane	338
1,2,2-Trimethyl-3-carbomethoxy-cyclopentane-1-carboxaldehyde	C ₂ H ₅ MgBr	β -Ethyl- β -campholide [†] (37-40%); 1,2,2-trimethyl-1-propenyl-3-(Δ^2 -3-pentenyl)cyclopentane; 1,8,8-trimethyl-2,4,4-triethyl-3-oxabicyclo[3.2.1]octane; 1,2,2-trimethyl-1-(1-hydroxypropyl)-3-(Δ^2 -3-pentenyl)cyclopentane; 1,2,2-trimethyl-1-(1-hydroxypropyl)-3-(3-hydroxy-3-pentyl)cyclopentane	337,338
1,2,2-Trimethyl-3-carbomethoxy-cyclopentane-1-carboxaldehyde	<i>n</i> -C ₃ H ₇ MgBr	β - <i>n</i> -Propyl- β -campholide (3%); probably some β -campholide	337
1,2,2-Trimethyl-3-carbomethoxy-cyclopentane-1-carboxaldehyde	<i>n</i> -C ₄ H ₉ MgBr	β - <i>n</i> -Butyl- β -campholide; β -campholide	337
1,2,2-Trimethyl-3-carbomethoxy-cyclopentane-1-carboxaldehyde	C ₆ H ₅ MgBr (2 equiv.)	β -Phenyl- β -campholide	337
1,2,2-Trimethyl-3-carbomethoxy-cyclopentane-1-carboxaldehyde	C ₆ H ₅ CH ₂ MgCl	β -Benzyl- β -campholide	337

* 4,5,8,8-Tetramethyl-3-oxabicyclo[3.2.1]octan-2-one.

[†] 4-Ethyl-5,8,8-trimethyl-3-oxabicyclo[3.2.1]octan-2-one.

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₂₀O₃			
H ₅ C ₂ O ₂ C(CH ₂) ₇ CHO	<i>n</i> -C ₃ H ₇ MgI	<i>n</i> -C ₃ H ₇ CH(OH)(CH ₂) ₇ CO ₂ C ₂ H ₅	7
H ₃ CO ₂ C(CH ₂) ₈ CHO	(CH ₂) ₄ CHCH ₂ MgBr	(CH ₂) ₄ CHCH ₂ CH(OH)(CH ₂) ₈ CO ₂ CH ₃	251
H ₃ CO ₂ C(CH ₂) ₈ CHO (48.0 g.)	(CH ₂) ₅ CHMgBr	(CH ₂) ₅ CH[H ₃ CO ₂ C(CH ₂) ₈]CHOH (15.4 g., 23%)	426
H ₃ CO ₂ C(CH ₂) ₈ CHO (47 g.)	(CH ₂) ₅ CHCH ₂ CH ₂ MgBr	(CH ₂) ₅ CHCH ₂ CH ₂ [H ₃ CO ₂ C(CH ₂) ₈]CHOH (10 g., 14%)	426
H ₃ CO ₂ C(CH ₂) ₈ CHO (45 g.)	<i>n</i> -C ₈ H ₁₇ MgBr (1 equiv.)	<i>n</i> -C ₈ H ₁₇ CH(OH)(CH ₂) ₈ CO ₂ CH ₃ (25 g.)	322
C₁₁H₂₃ON			
(<i>n</i> -C ₃ H ₇) ₂ NCH ₂ (CH ₃) ₂ CCHO	4-CH ₃ OC ₁₀ H ₆ -1-MgBr	4-CH ₃ O-1-C ₁₀ H ₆ [(<i>n</i> -C ₃ H ₇) ₂ NCH ₂ (CH ₃) ₂ C]CHOH	159
C₁₂H₂₀O₃			
1,2,2-Trimethyl-3-carbethoxy-cyclopentane-1-carboxaldehyde	C ₂ H ₅ MgBr	β-Ethyl-β-campholide	337
C₁₂H₂₂O₃			
H ₅ C ₂ O ₂ C(CH ₂) ₈ CHO (96 g., 0.45 mole)	<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ MgCl (61 g., 0.5 mole C ₆ H ₁₃ Cl)	<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ [H ₅ C ₂ O ₂ C(CH ₂) ₈]CHOH (70%)	435
H ₅ C ₂ O ₂ C(CH ₂) ₈ CHO (96 g., 0.45 mole)	<i>t</i> -C ₄ H ₉ (CH ₂) ₄ MgCl (75 g., 0.5 mole C ₈ H ₁₇ Cl)	<i>t</i> -C ₄ H ₉ (CH ₂) ₄ [H ₅ C ₂ O ₂ C(CH ₂) ₈]CHOH (63%)	435
H ₃ CO ₂ C(CH ₂) ₉ CHO (16 g.)	<i>n</i> -C ₇ H ₁₅ MgBr (1 equiv.)	<i>n</i> -C ₇ H ₁₅ [H ₃ CO ₂ C(CH ₂) ₉]CHOH (10 g.)	322
C₁₂H₂₄O			
<i>n</i> -C ₁₁ H ₂₃ CHO	<i>n</i> -C ₄ H ₉ MgCl	<i>n</i> -C ₄ H ₉ (<i>n</i> -C ₁₁ H ₂₃)CHOH (58%)	8
CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCHO (36.8 g., 0.2 mole)	<i>t</i> -C ₅ H ₁₁ MgCl (0.4 mole)	CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCH ₂ OH (90%)	358
C₁₃H₁₂O₂			
2-Ethoxy-1-naphthalene-carboxaldehyde (20 g.)	9-Phenanthryl-MgBr	2-Ethoxy-1-naphthyl-9-phenanthryl-methanol (22 g., 58%)	24

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₂₄O₃ H ₃ CO ₂ C(CH ₂) ₁₀ CHO (38 g.)	<i>n</i> -C ₆ H ₁₃ MgBr (1 equiv.)	<i>n</i> -C ₆ H ₁₃ CH(OH)(CH ₂) ₁₀ CO ₂ CH ₃ (13 g.)	322
C₁₃H₂₇ON (<i>n</i> -C ₄ H ₉) ₂ NCH ₂ (CH ₃) ₂ CCHO	4-CH ₃ OC ₁₀ H ₆ -1-MgBr	4-CH ₃ O-1-C ₁₀ H ₆ [(<i>n</i> -C ₄ H ₉) ₂ NCH ₂ (CH ₃) ₂ C]CHOH	161
C₁₄H₁₂O (C ₆ H ₅) ₂ CHCHO (98 g.)	4-CH ₃ OC ₆ H ₄ MgBr (140 g. C ₇ H ₇ BrO)	4-CH ₃ OC ₆ H ₄ [(C ₆ H ₅) ₂ CH]CHOH (150 g.)	196
C₁₄H₁₂O₂ 3-C ₆ H ₅ CH ₂ OC ₆ H ₄ CHO 4-C ₆ H ₅ CH ₂ OC ₆ H ₄ CHO	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg (C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	(C ₂ H ₅) ₂ N(CH ₂) ₃ CH(OH)C ₆ H ₄ -3-CH ₂ OC ₆ H ₅ (C ₂ H ₅) ₂ N(CH ₂) ₃ CH(OH)C ₆ H ₄ -4-CH ₂ OC ₆ H ₅	233 233
C₁₄H₂₂O RCH=CHCH(CH ₃)CHO* (10.8 g.)	C ₂ H ₅ OCH ₂ CH=C(CH ₃)C≡CMgBr (6.5 g. C ₈ H ₁₂ O)	RCH=CHCH(CH ₃)CH(OH)C≡CC(CH ₃)=CHCH ₂ OC ₂ H ₅ *	235
RCH ₂ CH=C(CH ₃)CHO*† (17 g.)	(≡CMgBr) ₂ (27 g. C ₂ H ₅ Br)	[≡CCH(OH)C(CH ₃)=CHCH ₂ R] ₂ *	147
RCH ₂ CH=C(CH ₃)CHO*†	BrMgOCH ₂ CH=CHC≡CMgBr	RCH ₂ CH=C(CH ₃)CH(OH)C≡CCH=CHCH ₂ OH (11 g., crude)	404
RCH ₂ CH=C(CH ₃)CHO*† (72.0 g.)	BrMgOCH ₂ CH=C(CH ₃)C≡CMgBr (39.6 g. C ₆ H ₈ O)	RCH ₂ CH=C(CH ₃)CH(OH)C≡CC(CH ₃)=CHCH ₂ OH* (85.0 g., 81%)	402, 141
RCH ₂ CH=C(CH ₃)CHO*† (3.5 g.)	<i>n</i> -C ₄ H ₉ C≡CMgBr (5.0 g. C ₆ H ₁₀)	RCH ₂ CH=C(CH ₃)CH(OH)C≡C- <i>n</i> -C ₄ H ₉ * (4.5 g., 92%)	403

* R = 2,6,6-Trimethyl-1-cyclohexenyl.

† This is the so-called "β-ionone C₁₄ aldehyde" (402, 403).

TABLE VI-XVII (Continued)

Aldehyde	RMgX	Product(s)	Ref.
C₁₄H₂₂O (<i>cont.</i>)			
RCH ₂ CH=C(CH ₃)CHO* †	CH ₃ OCH ₂ CH=C(CH ₃)C≡CMgBr	RCH ₂ CH=C(CH ₃)CH(OH)C≡CC(CH ₃)=CHCH ₂ OCH ₃ *	157
RCH ₂ CH=C(CH ₃)CHO* † (5.15 g.)	CH ₃ OCH(CH ₃)CH=CHC≡CMgBr (6 g. C ₇ H ₁₀ O)	RCH ₂ CH=C(CH ₃)CH(OH)C≡CCH=CHCH(CH ₃)OCH ₃ * (5.7 g., 94% on basis of aldehyde consumed); recovered aldehyde (1.2 g., 23%)	403
RCH ₂ CH=C(CH ₃)CHO* † (30.0 g.)	<i>n</i> -C ₄ H ₉ OCH ₂ CH=C(CH ₃)C≡CMgBr (31.0 g. C ₁₀ H ₁₆ O)	RCH ₂ CH=C(CH ₃)CH(OH)C≡CC(CH ₃)=CHCH ₂ O- <i>n</i> -C ₄ H ₉ * (41.5 g.)	157
RCH ₂ CH=C(CH ₃)CHO* † (39.3 g.)	C ₆ H ₅ OCH ₂ CH=C(CH ₃)C≡CMgBr (36.6 g. C ₁₂ H ₁₂ O)	RCH ₂ CH=C(CH ₃)CH(OH)C≡CC(CH ₃)=CHCH ₂ OC ₆ H ₅ * (20.0 g.)	157
C₁₄H₂₆O₃			
H ₅ C ₂ O ₂ C(CH ₂) ₁₀ CHO (50 g., 0.2 mole)	<i>t</i> -C ₄ H ₉ (CH ₂) ₄ MgCl (30 g., 0.2 mole C ₈ H ₁₇ Cl)	<i>t</i> -C ₄ H ₉ (CH ₂) ₄ [H ₅ C ₂ O ₂ C(CH ₂) ₁₀]CHOH (57 g.)	435
H ₃ CO ₂ C(CH ₂) ₁₁ CHO	(CH ₂) ₄ CHMgBr	(CH ₂) ₄ CHCH(OH)(CH ₂) ₁₁ CO ₂ CH ₃ ; H ₃ CO ₂ C(CH ₂) ₁₁ CH ₂ OH; [H ₃ CO ₂ C(CH ₂) ₁₁ CH(OH)—] ₂	251
H ₃ CO ₂ C(CH ₂) ₁₁ CHO (41 g.)	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₅ H ₁₁ CH(OH)(CH ₂) ₁₁ CO ₂ CH ₃ (10 g.)	322
H ₃ CO ₂ C(CH ₂) ₁₁ CHO (72.6 g.)	(CH ₂) ₅ CHMgBr (1 equiv.)	(CH ₂) ₅ CHCH(OH)(CH ₂) ₁₁ CO ₂ CH ₃ (13.5 g.)	140
C₁₅H₁₀O			
2-Phenanthrenecarboxaldehyde	C ₆ H ₅ MgBr	Phenyl-2-phenanthrylmethanol (80%)	12
3-Phenanthrenecarboxaldehyde	C ₆ H ₅ MgBr	Phenyl-3-phenanthrylmethanol (64%)	12
9-Phenanthrenecarboxaldehyde (20 g.)	1-C ₁₀ H ₇ MgBr (20 g. C ₁₀ H ₇ Br)	1-Naphthyl-9-phenanthrylmethanol	23

* R = 2,6,6-Trimethyl-1-cyclohexenyl.

† This is the so-called "β-ionone C₁₄ aldehyde" (402, 403).

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₀O (<i>cont.</i>)			
9-Phenanthrenecarboxaldehyde (11 g.)	2-CH ₃ C ₁₀ H ₆ -1-MgBr (11 g. C ₁₁ H ₉ Br)	2-Methyl-1-naphthyl-9-phenanthrylmethanol	24
9-Anthraldehyde (30 g.)	CH ₃ MgI (21.5 g. CH ₃ I)	1-(9-Anthracyl)ethanol (29.6 g., 92%)	89
9-Anthraldehyde (5.0 g.)	C ₆ H ₅ MgBr	Phenyl-9-anthracylmethanol (3.3 g.)	165
C₁₅H₁₂O₄			
3-CH ₃ O-4-C ₆ H ₅ CO ₂ C ₆ H ₃ CHO	CH ₃ MgI	CH ₃ (3-CH ₃ O-4-C ₆ H ₅ CO ₂ C ₆ H ₃)CHOH (85%)	91
3-CH ₃ O-4-C ₆ H ₅ CO ₂ C ₆ H ₃ CHO	<i>n</i> -C ₃ H ₇ MgI	<i>n</i> -C ₃ H ₇ (3-CH ₃ O-4-C ₆ H ₅ CO ₂ C ₆ H ₃)CHOH (31.5%)	144
3-CH ₃ O-4-C ₆ H ₅ CO ₂ C ₆ H ₃ CHO	<i>n</i> -C ₄ H ₉ MgI	<i>n</i> -C ₄ H ₉ (3-CH ₃ O-4-C ₆ H ₅ CO ₂ C ₆ H ₃)CHOH (48%)	144
3-CH ₃ O-4-C ₆ H ₅ CO ₂ C ₆ H ₃ CHO	<i>n</i> -C ₅ H ₁₁ MgI	<i>n</i> -C ₅ H ₁₁ (3-CH ₃ O-4-C ₆ H ₅ CO ₂ C ₆ H ₃)CHOH (48%)	144
C₁₅H₁₄O			
CH ₃ (C ₆ H ₅) ₂ CCHO (14 g.)	CH ₃ MgI (1.25 equiv.)	CH ₃ [CH ₃ (C ₆ H ₅) ₂ C]CHOH (11 g.)	207
CH ₃ (C ₆ H ₅) ₂ CCHO (21 g.)	C ₆ H ₅ MgBr (1.25 equiv.)	C ₆ H ₅ [CH ₃ (C ₆ H ₅) ₂ C]CHOH (17 g.)	207
C ₆ H ₅ (C ₆ H ₅ CH ₂)CHCHO	C ₆ H ₅ MgBr	C ₆ H ₅ [C ₆ H ₅ (C ₆ H ₅ CH ₂)CH]CHOH, α form	433
DL-C ₆ H ₅ (C ₆ H ₅ CH ₂)CHCHO	C ₆ H ₅ MgBr	α -DL-C ₆ H ₅ [C ₆ H ₅ (C ₆ H ₅ CH ₂)CH]CHOH, m, 92°	318
C₁₅H₃₁ON			
(<i>n</i> -C ₅ H ₁₁) ₂ NCH ₂ (CH ₃) ₂ CCHO	4-CH ₃ OC ₁₀ H ₆ -1-MgBr	4-CH ₃ O-1-C ₁₀ H ₆ [(<i>n</i> -C ₅ H ₁₁) ₂ NCH ₂ (CH ₃) ₂ C]CHOH	161
C₁₆H₁₆O			
C ₂ H ₅ (C ₆ H ₅) ₂ CCHO	CH ₃ MgI (1.25 equiv.)	CH ₃ [C ₂ H ₅ (C ₆ H ₅) ₂ C]CHOH	207

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₁₆O (<i>cont.</i>)			
(C ₆ H ₅ CH ₂) ₂ CHCHO	4-CH ₃ OC ₆ H ₄ MgBr	4-CH ₃ OC ₆ H ₄ [(C ₆ H ₅ CH ₂) ₂ CH]CHOH	319
C₁₆H₂₄O			
2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ CHO (69.6 g.)	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ [2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂]CHOH (75 g., crude)	102
C₁₇H₁₃O₂			
2-Phenyl-6-methoxyquinoline-4-carboxaldehyde (5.0 g., 0.019 mole)	(C ₂ H ₅) ₂ N(CH ₂) ₃ MgCl (8.5 g., 0.057 mole C ₇ H ₁₆ ClN)	α -(3-Diethylaminopropyl)-2-phenyl-6-methoxy-4-quinolinemethanol (isolated as hydrochloride, 8.3 g., 97%)	112
2-Phenyl-6-methoxyquinoline-4-carboxaldehyde (5.0 g., 0.019 mole)	(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₃ MgCl (11.7 g., 0.057 mole C ₁₁ H ₂₄ ClN)	α -(3-Di- <i>n</i> -butylaminopropyl)-2-phenyl-6-methoxy-4-quinolinemethanol (isolated as hydrochloride, 5.0 g., 52%)	112
C₁₇H₁₅O₅			
(-)-C ₆ H ₅ CO ₂ CH ₂ CH(O ₂ CC ₆ H ₅)CHO	C ₆ H ₅ MgBr	C ₆ H ₅ CO ₂ CH ₂ CH(O ₂ CC ₆ H ₅)CH(C ₆ H ₅)OH, α (-) form	320
C₁₇H₁₈O			
CH ₃ (C ₆ H ₅ CH ₂) ₂ CCHO	CH ₃ MgI	CH ₃ [CH ₃ (C ₆ H ₅ CH ₂) ₂ C]CHOH	208
C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂]CHCHO (0.5 g.)	C ₆ H ₅ MgBr (0.505 g. C ₆ H ₅ Br)	C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂]CHCH(C ₆ H ₅)OH	103
C₁₇H₂₂O₃			
Benzyl 1-formyl-1,2,2-trimethylcyclopentane-3-carboxylate	C ₂ H ₅ MgBr	β -Ethyl- β -campholide* (25%)	337

* 4-Ethyl-5,8,8-trimethyl-3-oxabicyclo[3.2.1]octan-2-one.

TABLE VI-XVII (Continued)

<u>Aldehyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₂₄O RCH=CHC(CH ₃)=CHCH=CHCHO*	C ₂ H ₅ OC≡CMgBr	C ₂ H ₅ OC≡C[RCH=CHC(CH ₃)=CHCH=CH]CHOH*	384
C₁₈H₃₄O₃ H ₅ C ₂ O ₂ C(CH ₂) ₁₄ CHO (0.25 mole)	<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ MgCl (0.25 mole C ₆ H ₁₃ Cl)	<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ [H ₅ C ₂ O ₂ C(CH ₂) ₁₄]CHOH	435
H ₅ C ₂ O ₂ C(CH ₂) ₁₄ CHO	<i>t</i> -C ₄ H ₉ (CH ₂) ₄ MgCl	<i>t</i> -C ₄ H ₉ (CH ₂) ₄ [H ₅ C ₂ O ₂ C(CH ₂) ₁₄]CHOH	435
C₁₉H₁₂O 7-Benz[<i>a</i>]anthracenecarboxaldehyde	CH ₃ MgI	1-(7-Benz[<i>a</i>]anthracyl)ethanol (56%)	89
C₂₀H₃₆O₂ Citronellal aldol [RCH ₂ CH(OH)CHRCHO]† (25.0 g., 0.0815 mole)	C ₆ H ₅ MgBr (0.241 mole)	RCH ₂ CH(OH)CHRCH(OH)C ₆ H ₅ † (23.8 g.)	452
C₂₁H₁₄O 10-Phenyl-9-anthraldehyde (8.3 g.)	C ₆ H ₅ MgBr (2.4 g. Mg)	9-Phenyl-10-(α -hydroxybenzyl)anthracene (3.5 g.)	165
C₂₂H₂₀O C ₆ H ₅ (4-CH ₃ C ₆ H ₄) ₂ CCHO	C ₆ H ₅ MgBr (3 equiv.)	C ₆ H ₅ [C ₆ H ₅ (4-CH ₃ C ₆ H ₄) ₂ C]CHOH	207
C₃₀H₄₀O β -Apo-2-carotinal (90 mg.)	C ₂ H ₅ MgBr (0.3 g. C ₂ H ₅ Br)	Corresponding secondary alcohol (39 mg.)	168

* R = 2,6,6-Trimethyl-1-cyclohexenyl.

† R = (CH₃)₂C=CH(CH₂)₂CH(CH₃)—.

REFERENCES FOR TABLE VI-XVII

- (1) Abelman, *Ber.*, 40, 4589-90 (1907).
- (2) Adams, Harfenist, and Loewe, *J. Am. Chem. Soc.*, 71, 1624-8 (1949).
- (3) Adams and Noller, *Organic Syntheses*, 6, 22-5 (1926); 7, 90 (1927); 8, 124 (1928).
- (4) Alles, Icke, and Feigen, *J. Am. Chem. Soc.*, 64, 2031-5 (1942).
- (5) Arbuzov, *J. Gen. Chem. (U.S.S.R.)*, 9, 249-54 (1939); *Chem. Abstr.*, 33, 6279 (1939).
- (6) Arcus and Kenyon, *J. Chem. Soc.*, 1938, 312-8.
- (7) Asano, *J. Pharm. Soc., Japan*, 1927, No. 544, 76-7; *Chem. Zentr.*, 1927, II, 1016.
- (8) Asinger and Eckholdt, *Ber.*, 76B, 579-84 (1943).
- (9) Austerweil and Cochlin, *Compt. rend.*, 151, 440-1 (1911); *Chem. Abstr.*, 5, 2091 (1911).
- (10) Bachmann, *J. Am. Chem. Soc.*, 55, 2135-9 (1933).
- (11) Bachmann, *J. Am. Chem. Soc.*, 56, 1363-7 (1934).
- (12) Bachmann, *J. Am. Chem. Soc.*, 57, 555-9 (1935).
- (13) Bachmann and Ferguson, *J. Am. Chem. Soc.*, 56, 2081-4 (1934).
- (14) Bachmann, Hoffman, and Whitehead, *J. Org. Chem.*, 8, 320-30 (1943).
- (15) Bachman and Lewis, *J. Am. Chem. Soc.*, 69, 2022-5 (1947).
- (16) Backer and Bolt, *Rec. trav. chim.*, 54, 68-72 (1935).
- (17) Baker and Smith, *J. Chem. Soc.*, 1936, 346-8.
- (18) Baker and Squire, *J. Am. Chem. Soc.*, 70, 1487-90 (1948).
- (19) Bartlett and Rosen, *J. Am. Chem. Soc.*, 64, 543-6 (1942).
- (20) Baudrenghien, *Bull. soc. chim. Belg.*, 31, 160-70 (1922).
- (21) Béhal and Tiffeneau, *Bull. soc. chim.*, [4], 3, 301-10 (1908).
- (22) Bergmann and Bergmann, *J. Am. Chem. Soc.*, 59, 1443-50 (1937).
- (23) Bergmann and Israelashvili, *J. Am. Chem. Soc.*, 68, 1-5 (1946).
- (24) Bergmann and Israelashvili, *J. Am. Chem. Soc.*, 68, 354-6 (1946).
- (25) Bergmann, Weizman, and Schapiro, *J. Org. Chem.*, 9, 408-14 (1944).
- (26) Bergkvist, *Svensk. Kem. Tid.*, 59, 27-30 (1947); *Chem. Abstr.*, 41, 5095 (1947).
- (27) Bert, *Bull. soc. chim.*, [4], 37, 1577-91 (1925).
- (28) Betti and Lucchi, *Boll. sci. facolta chim. ind., Bologna*, 1940, No. 1-2, 2-5; *Chem. Abstr.*, 34, 2354 (1940).
- (29) Billeter and Miescher, *Helv. Chim. Acta*, 29, 859-71 (1946).
- (30) Bjelouss, *Ber.*, 43, 2330-3 (1910).
- (31) Bogert and Davidson, *J. Am. Chem. Soc.*, 56, 185-90 (1934).
- (32) Bogert, Davidson, and Appelbaum, *J. Am. Chem. Soc.*, 56, 959-63 (1934).
- (33) Bouis, *Ann. chim.*, [10], 9, 402-65 (1928).
- (34) Bourgom, *Bull. soc. chim. Belg.*, 33, 101-15 (1924).
- (35) Bouveault, *Bull. soc. chim.*, [3], 29, 1049-51 (1903).
- (36) Brachin, *Bull. soc. chim.*, [3], 35, 1163-79 (1906).
- (37) Bradsher, *J. Am. Chem. Soc.*, 66, 45-6 (1944).
- (38) Bradsher and Amore, *J. Am. Chem. Soc.*, 63, 493-5 (1941).
- (39) Brewin and Turner, *J. Chem. Soc.*, 1930, 502-4.
- (40) Burton, *J. Chem. Soc.*, 1929, 455-8.
- (41) Burton and Ingold, *J. Chem. Soc.*, 1928, 904-21.
- (42) Byrtschenko, *J. Russ. Phys.-Chem. Soc.*, 42, 876-9 (1910); *Chem. Zentr.*, 1910, II, 1744.
- (43) Calingaert and Soroos, *J. Am. Chem. Soc.*, 58, 635-6 (1936).
- (44) Campbell, Campbell, and McGuire, *Proc. Indiana Acad. Sci.*, 50, 87-93 (1940); *Chem. Abstr.*, 35, 5872 (1941).

- (45) Campbell and McGuire, *Proc. Indiana Acad. Sci.*, 50, 87-93 (1940); *Chem. Abstr.*, 35, 5872 (1941).
- (46) Cason, Adams, Bennett, and Register, *J. Am. Chem. Soc.*, 66, 1764-7 (1944).
- (47) Chu and Marvel, *J. Am. Chem. Soc.*, 53, 4449 (1931).
- (48) Claisen and Tietze, *Ber.*, 59B, 2344-51 (1926).
- (49) Clarke, *J. Am. Chem. Soc.*, 30, 1144-52 (1908).
- (50) Clarke, *J. Am. Chem. Soc.*, 31, 107-16 (1909).
- (51) Clément, *Compt. rend.*, 207, 864-6 (1938); *Chem. Abstr.*, 33, 7747 (1939).
- (52) Clément, *Ann. chim.*, [11], 13, 243-316 (1940).
- (53) Coburn, *Organic Syntheses*, 27, 65-7 (1947).
- (54) Colacicchi, *Atti accad. Lincei*, [5], 19, 11, 600-5 (1910); *Chem. Zentr.*, 1911, I, 382.
- (55) Conant, Webb, and Mendum, *J. Am. Chem. Soc.*, 51, 1246-55 (1929).
- (56) Consden, Duveen, and Kenyon, *J. Chem. Soc.*, 1938, 2104-6.
- (57) Cook and Stamper, *J. Am. Chem. Soc.*, 69, 1467-8 (1947).
- (58) Cottle and Hollyday, *J. Org. Chem.*, 12, 510-6 (1947).
- (59) Courtot, *Bull. soc. chim.*, [3], 35, 969-88 (1906).
- (60) Courtot, *Ann. chim.*, [9], 4, 58-136 (1915).
- (61) Coyner and Ropp, *J. Am. Chem. Soc.*, 69, 2231-2 (1947).
- (62) Dauben, *J. Am. Chem. Soc.*, 70, 1376-8 (1948).
- (63) Davies, Dixon, and Jones, *J. Chem. Soc.*, 1930, 468-73.
- (64) Dean and Wolf, *J. Am. Chem. Soc.*, 58, 332-3 (1936).
- (65) Deemer, Lutwak, and Strong, *J. Am. Chem. Soc.*, 70, 154-7 (1948).
- (66) Delaby, *Bull. soc. chim.*, [4], 27, 609-11 (1920).
- (67) Delaby, *Compt. rend.*, 175, 167-70 (1922).
- (68) Delaby, *Compt. rend.*, 175, 967-70 (1922).
- (69) Delaby, *Compt. rend.*, 194, 1248-50 (1932).
- (70) Delaby, *Ann. chim.*, [9], 19, 275-326 (1923).
- (71) Delaby, *Bull. soc. chim.*, [4], 33, 602-26 (1923).
- (72) Delaby and Guillot-Allegre, *Bull. soc. chim.*, [4], 53, 301-20 (1933).
- (73) Delepine, *Compt. rend.*, 150, 535-7 (1910); *Chem. Zentr.*, 1910, I, 1495.
- (74) Deluchat, *Ann. chim.*, [11], 1, 181-255 (1934).
- (75) Doering and Beringer, *J. Am. Chem. Soc.*, 71, 2221-6 (1949).
- (76) Doeuvre, *Bull. soc. chim.*, [4], 45, 403-12 (1929).
- (77) Doeuvre, *Bull. soc. chim.*, [4], 45, 710-5 (1929).
- (78) Douetteau, *Bull. soc. chim.*, [4], 11, 652-6 (1912).
- (79) Douris, *Compt. rend.*, 157, 943-5 (1913); *Chem. Zentr.*, 1914, I, 123.
- (80) Drake and Cooke, *Organic Syntheses*, Coll. Vol. II, pp. 406-7 (1943).
- (81) Dupont, *Ann. chim.*, [8], 30, 485-587 (1913).
- (82) Duveen and Kenyon, *Bull. soc. chim.*, [5], 5, 704-9 (1938).
- (83) Duveen and Kenyon, *Bull. soc. chim.*, [5], 5, 1120-6 (1938).
- (84) Edgar, Calingaert, and Marker, *J. Am. Chem. Soc.*, 51, 1483-91 (1929).
- (85) Edwards and Reid, *J. Am. Chem. Soc.*, 52, 3235-41 (1930).
- (86) Elderfield, Craig, Lauer, Arnold, Gensler, Head, Bemby, Mighton, Tinker, Galbreath, Holley, Goldman, Maynard, and Picus, *J. Am. Chem. Soc.*, 68, 1516-23 (1943).
- (87) Elderfield and Head, U. S. Patent 2,422,957, June 24, 1947; *Chem. Abstr.*, 41, P6274 (1947).
- (88) Fabinyi and Szeki, *Ber.*, 50, 1335-9 (1917).
- (89) Fieser and Hartwell, *J. Am. Chem. Soc.*, 60, 2555-9 (1938).
- (90) Fieser and Seligman, *J. Am. Chem. Soc.*, 61, 136-42 (1939).
- (91) Finnemore, *J. Chem. Soc.*, 93, 1520-4 (1908).

- (92) Fischer and Baer, *Helv. Chim. Acta*, 18, 514-21 (1935).
(93) Fischer and Zeile, *Ann.*, 462, 210-30 (1928).
(94) Floutz, *J. Am. Chem. Soc.*, 65, 2255 (1943).
(95) Floutz, *J. Am. Chem. Soc.*, 67, 1615-6 (1945).
(96) Floutz, *J. Am. Chem. Soc.*, 68, 2490-1 (1946).
(97) Floutz, *J. Am. Chem. Soc.*, 71, 2859-60 (1949).
(98) Fourneau and Ramart-Lucas, *Bull. soc. chim.*, [4], 25, 364-70 (1919).
(99) Fourneau and Tiffeneau, *Compt. rend.*, 145, 437-9 (1907); *Chem. Zentr.*, 1907,II, 1320.
(100) Franke and Kohn, *Monatsh.*, 27, 1097-128 (1906).
(101) Freundler, *Compt. rend.*, 142, 343-5 (1906); *Chem. Zentr.*, 1906,I, 934.
(102) Fuson, Denton, and Best, *J. Org. Chem.*, 8, 64-72 (1943).
(103) Fuson and Tan, *J. Am. Chem. Soc.*, 70, 602-5 (1948).
(104) Garach, *Groupeement franc. develop. recherches aeronaut.*, Note tech. No. 15, 30 pp. (1944); *Chem. Abstr.*, 43, 2156 (1949).
(105) Gauthier and Gauthier, *Bull. soc. chim.*, [4], 53, 323-6 (1933).
(106) Gérard, *Bull. acad. roy. Belg., Classe sci.*, 1906, 790-5; *Chem. Zentr.*, 1907,I, 1398.
(107) Gilman and Abbot, *J. Org. Chem.*, 8, 224-9 (1943).
(108) Gilman and Catlin, *Organic Syntheses*, Coll. Vol. I, 1st ed., pp. 182-5 (1932); 2nd ed., pp. 188-90 (1941).
(109) Gilman and Franz, *Rec. trav. chim.*, 51, 991-5 (1932).
(110) Gilman and Kirby, *J. Am. Chem. Soc.*, 51, 3475-8 (1929).
(111) Gilman and Kirby, *J. Am. Chem. Soc.*, 54, 345-55 (1932).
(112) Gilman, Marshall, and Benkeser, *J. Am. Chem. Soc.*, 68, 1849-50 (1946).
(113) Gilman and Schulz, *J. Am. Chem. Soc.*, 52, 3588-90 (1930).
(114) Gorski, *J. Russ. Phys.-Chem. Soc.*, 42, 1356-8 (1910); *Chem. Zentr.*, 1911,I, 635.
(115) Grard, *Compt. rend.*, 189, 541-3 (1929).
(116) Grédy, *Compt. rend.*, 199, 153-4 (1934); *Chem. Abstr.*, 28, 6117 (1934).
(117) Grédy, *Bull. soc. chim.*, [5], 2, 1038-44 (1935).
(118) Grédy, *Bull. soc. chim.*, [5], 3, 1093-101 (1936).
(119) Grignard, *Ann. Univ. Lyon, N.S.*, 6, 1-116 (1901); *Chem. Zentr.*, 1901,II, 622.
(120) Grignard, *Compt. rend.*, 130, 1322-4 (1900); *J. Chem. Soc.*, 78,I, 382 (1900).
(121) Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).
(122) Grignard and Courtot, *Compt. rend.*, 160, 500-4 (1915); *Chem. Zentr.*, 1915,II, 406.
(123) Grundmann, *Chem. Ber.*, 81, 513-9 (1948); *Chem. Abstr.*, 43, 5376 (1949).
(124) Grunert, Nichol, and Sandin, *J. Am. Chem. Soc.*, 69, 2254-6 (1947).
(125) Grüttner and Cauer, *Ber.*, 51, 1283-92 (1918).
(126) Heilbron, Jones, Lewis, Richardson, and Weedon, *J. Chem. Soc.*, 1949, 742-6.
(127) Heilbron, Jones, and Raphael, *J. Chem. Soc.*, 1943, 264-5.
(128) Hell, *Ber.*, 37, 453-8 (1904).
(129) Hell and Hofmann, *Ber.*, 37, 4188-93 (1904).
(130) Hell and Hofmann, *Ber.*, 38, 1676-80 (1905).
(131) Hell and Wiegandt, *Ber.*, 37, 1429-32 (1904).
(132) Henry, *Compt. rend.*, 138, 205-6 (1904); *J. Chem. Soc.*, 86,I, 279 (1904).
(133) Henry, *Compt. rend.*, 144, 308-13 (1907); *Chem. Zentr.*, 1907,I, 1102.
(134) Henry, *Bull. acad. roy. Belg., Classe sci.*, 1907, 162-89; *Chem. Zentr.*, 1907,II, 445.
(135) Henry and Dewael, *Bull. acad. roy. Belg., Classe sci.*, 1908, 857-63; *Chem. Zentr.*, 1909,I, 1854.

- (136) Henze, Allen, and Leslie, *J. Org. Chem.*, 7, 326-35 (1942).
(137) Hess and Rheinboldt, *Ber.*, 54B, 2043-55 (1921).
(138) Hess and Wustrow, *Ann.*, 434, 256-73 (1924).
(139) Salkind and Issakovitch, *J. Russ. Phys.-Chem. Soc.*, 45, 1896-903 (1914); *Bull. soc. chim.*, [4], 16, 546 (1914).
(140) Hiers and Adams, *J. Am. Chem. Soc.*, 48, 1089-93 (1926).
(141) Hoffmann-LaRoche & Co. A.-G., Swiss Patent 250,374, July 1, 1948; *Chem. Abstr.*, 43, P7959 (1949).
(142) Howard, *J. Am. Chem. Soc.*, 48, 774-5 (1926).
(143) Howard, *J. Am. Chem. Soc.*, 49, 1068-9 (1927).
(144) Howells, Little, and Andersen, *J. Am. Chem. Soc.*, 52, 4076-82 (1930).
(145) Howiz and Kopke, *Ann.*, 396, 38-52 (1913).
(146) Hurd and Cohen, *J. Am. Chem. Soc.*, 53, 1917-22 (1931).
(147) Inhoffen, Pommer, and Bohlmann, *Ann.*, 561, 26-31 (1948).
(148) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 34, 241-2 (1902); *Bull. soc. chim.*, [3], 30, 209 (1903).
(149) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 34, 242-4 (1902); *Bull. soc. chim.*, [3], 30, 210 (1903).
(150) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 35, 430-1 (1903); *Bull. soc. chim.*, [3], 32, 551, (1904).
(151) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 35, 1269-75 (1905); *Bull. soc. chim.*, [3], 34, 181 (1905).
(152) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 36, 8-9 (1904); *Bull. soc. chim.*, [3], 34, 204 (1905).
(153) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 36, 443-6 (1904); *Bull. soc. chim.*, [3], 34, 329 (1905).
(154) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 38, 252-3 (1906); *Bull. soc. chim.*, [4], 4, 981 (1908).
(155) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 38, 656-9 (1906); *Bull. soc. chim.*, [4], 4, 1203 (1908).
(156) Isler, Kofler, Huber, and Ronco, *Experientia*, 2, 31 (1946); *Chem. Abstr.*, 40, 4032 (1946).
(157) Isler, Ronco, Guex, Hindley, Huber, Dialer, and Kofler, *Helv. Chim. Acta*, 32, 489-505 (1949).
(158) Ivanoff and Nicoloff, *Bull. soc. chim.*, [4], 51, 1325-31 (1932).
(159) Jacobs, *J. Org. Chem.*, 11, 223-8 (1946).
(160) Jacobs, Cramer, and Weiss, *J. Am. Chem. Soc.*, 62, 1849-54 (1940).
(161) Jacobs, Winstein, Linden, and Seymour, *J. Org. Chem.*, 11, 223-8 (1946).
(162) Jaworsky, *Ber.*, 42, 435-8 (1909).
(163) Johnston and Williams, *J. Am. Chem. Soc.*, 69, 2065 (1947).
(164) Jolkver, *Rec. trav. chim.*, 28, 439-43 (1909).
(165) Julian, Cole, Diemer, and Schafer, *J. Am. Chem. Soc.*, 71, 2058-61 (1949).
(166) Juvala, *Ber.*, 63B, 1989-2009 (1930).
(167) Karasev, *J. Gen. Chem. (U.S.S.R.)*, 10, 1699-703 (1940); *Chem. Abstr.*, 35, 3223 (1941).
(168) Karrer, Ruegger, and Geiger, *Helv. Chim. Acta*, 21, 1171-4 (1938).
(169) Karrer, Shibata, Wettstein, and Jacobowicz, *Helv. Chim. Acta*, 13, 1292-1308 (1930).
(170) Kayser, *Compt. rend.*, 199, 1424-7 (1934).
(171) Kenyon and Young, *J. Chem. Soc.*, 1938, 1452-4.
(172) Kharasch, Kleiger, Martin, and Mayo, *J. Am. Chem. Soc.*, 63, 2305-7 (1941).
(173) Kinney and Spliethoff, *J. Org. Chem.*, 14, 71-8 (1949).
(174) Kirrman, *Compt. rend.*, 184, 1463-5 (1927).

- (175) Klages, *Ber.*, 35, 2646-9 (1902).
(176) Klages, *Ber.*, 36, 3584-97 (1903).
(177) Klages, *Ber.*, 37, 2301-17 (1904).
(178) Klages, *Ber.*, 39, 2587-95 (1906).
(179) Klages and Klenk, *Ber.*, 39, 2552-5 (1906).
(180) Klimenko, *J. Russ. Phys.-Chem. Soc.*, 43, 212-3 (1911); *Chem. Zentr.*, 1911,I, 1852.
(181) Knorr, German Patent 544,388, Jan. 28, 1932; *Friedländer*, 18, 180-4 (1933).
(182) Koelsch, *J. Am. Chem. Soc.*, 54, 2045-8 (1932).
(183) Koelsch, *J. Am. Chem. Soc.*, 56, 480-4 (1934).
(184) Kohler, *Am. Chem. J.*, 31, 642-61 (1904).
(185) Kohler, *Am. Chem. J.*, 38, 511-61 (1907).
(186) Kohler and Blanchard, *J. Am. Chem. Soc.*, 57, 367-71 (1935).
(187) Kohler and Patch, *J. Am. Chem. Soc.*, 38, 1205-16 (1916).
(188) Korjukin, *J. Russ. Phys.-Chem. Soc.*, 43, 204-7 (1910); *Chem. Zentr.*, 1911,I, 1852.
(189) Krestinsky, *Ber.*, 55B, 2754-62 (1922).
(190) Krestinsky, *Ber.*, 55B, 2762-70 (1922).
(191) Krestinsky, *Ber.*, 55B, 2770-4 (1922).
(192) Kursanov and Solodkov, *Compt. rend. acad. sci. U.R.S.S.*, 27, 797-800 (1940); *Chem. Abstr.*, 35, 1770 (1941).
(193) Kuznetsov, *J. Gen. Chem. (U.S.S.R.)*, 9, 2263-8 (1939); *Chem. Abstr.*, 34, 5052 (1940).
(194) Kyriakides, *J. Am. Chem. Soc.*, 36, 657-63 (1914).
(195) Lagerev and Shamshurin, *J. Gen. Chem. (U.S.S.R.)*, 9, 199-202 (1939); *Chem. Abstr.*, 33, 6258 (1939).
(196) LaGrave, *Ann. chim.*, [10], 8, 363-446 (1927).
(197) Lautenschlager and Onsager, *Ber.*, 51, 602-5 (1918).
(198) Lépingle, *Bull. soc. chim.*, [4], 39, 864-73 (1926).
(199) Lespieau, *Compt. rend.*, 150, 113-4 (1910); *Chem. Zentr.*, 1910,I, 1001.
(200) Lespieau and Wakeman, *Bull. soc. chim.*, [4], 51, 384-400 (1932).
(201) Levene and Haller, *J. Biol. Chem.*, 76, 415-22 (1928).
(202) Levene and Harris, *J. Biol. Chem.*, 111, 735-8 (1935).
(203) Levene and Marker, *J. Biol. Chem.*, 93, 749-74 (1931).
(204) Levene and Marker, *J. Biol. Chem.*, 103, 299-309 (1933).
(205) Levina, *J. Gen. Chem. (U.S.S.R.)*, 7, 684-7 (1937); *Chem. Abstr.*, 31, 5772 (1937).
(206) Levina and Grinberg, *J. Gen. Chem. (U.S.S.R.)*, 7, 2306-8 (1937); *Chem. Abstr.*, 32, 509 (1938).
(207) Lévy, *Bull. soc. chim.*, [4], 29, 878-99 (1921).
(208) Lévy, *Bull. soc. chim.*, [4], 39, 67-72 (1926).
(209) Lévy and Pernot, *Bull. soc. chim.*, [4], 49, 1721-30 (1931).
(210) Lock, *Ber.*, 72B, 300-4 (1939).
(211) Lozac'h, *Bull. soc. chim.*, [5], 8, 519-21 (1941).
(212) Madelung and Oberwegner, *Ber.*, 65B, 931-41 (1932).
(213) Malengreau, *Bull. acad. roy. Belg., Classe Sci.*, 1906, 802-10; *Chem. Zentr.*, 1907,I, 1398.
(214) Malenok and Sologub, *J. Gen. Chem. (U.S.S.R.)*, 10, 150-3 (1940); *Chem. Abstr.*, 34, 7286 (1940).
(215) Malenok and Sologub, *J. Gen. Chem. (U.S.S.R.)*, 11, 983-90 (1941); *Chem. Abstr.*, 37, 355 (1943).
(216) Mameli, *Gazz. chim. ital.*, 34,I, 358-74 (1904); *Chem. Zentr.*, 1904,II, 214.

- (217) Mameli and Alagra, *Atti accad. Lincei*, [5], 14, II, 170-80 (1905); *Chem. Zentr.*, 1905, II, 895.
- (218) Marko and P'yankov, *Uchenye Zapiski Molotov. Gosudarst. Univ.*, 3, No. 4, 9-14 (1939); *Khim. Referat. Zhur.*, 4, No. 4, 49 (1941); *Chem. Abstr.*, 37, 5058 (1943).
- (219) Marshall, *J. Chem. Soc.*, 127, 2184-5 (1925).
- (220) Marvel, Allen, and Overberger, *J. Am. Chem. Soc.*, 68, 1088-91 (1946).
- (221) Marvel, Blomquist, and Vaughan, *J. Am. Chem. Soc.*, 50, 2810-2 (1928).
- (222) Marvel and Hein, *J. Am. Chem. Soc.*, 70, 1895-8 (1948).
- (223) Marvel, Saunders, and Overberger, *J. Am. Chem. Soc.*, 68, 1085-8 (1946).
- (224) Marxer, *Helv. Chim. Acta*, 24, 209-15E (1941).
- (225) Mascarelli and Pirona, *Atti X^o Congr. intern. chim.*, 3, 249-50 (1939); *Chem. Abstr.*, 33, 9314 (1939).
- (226) Matti and Barman, *Bull. soc. chim.*, [5], 2, 1742-4 (1935).
- (227) Mauthner, *J. prakt. chem.*, [2], 92, 194-201 (1915).
- (228) McPhee and Ball, *J. Am. Chem. Soc.*, 66, 1636-40 (1944).
- (229) Meisenheimer, *Ann.*, 442, 180-210 (1925).
- (230) Mermod and Simonis, *Ber.*, 39, 897-9 (1906).
- (231) Mermod and Simonis, *Ber.*, 41, 982-5 (1908).
- (232) Michiels, *Bull. acad. roy. Belg., Classe sci.*, 1912, 10-34; *Chem. Zentr.*, 1912, I, 1105; *Chem. Abstr.*, 6, 1611 (1912).
- (233) Miescher and Marxer, U. S. Patent 2,411,664, Nov. 26, 1946; *Chem. Abstr.*, 41, P6276 (1947).
- (234) Mihailescu and Caragea, *Bull. sect. sci. acad. romaine*, 12, No. 4/5, 7-18 (1929); *Chem. Abstr.*, 24, 2116 (1930).
- (235) Milas, U. S. Patent 2,412,465, Dec. 10, 1946; *Chem. Abstr.*, 41, P1240 (1947).
- (236) Mingoia, *Gazz. chim. ital.*, 62, 844-54 (1932); *Chem. Abstr.*, 27, 503 (1933).
- (237) Moureu, *Bull. soc. chim.*, [3], 33, 151-7 (1905).
- (238) Moureu and Gallagher, *Bull. soc. chim.*, [4], 29, 1009-17 (1921).
- (239) Mukherjee, *J. Indian Chem. Soc.*, 25, 155-64 (1948); *Chem. Abstr.*, 43, 2605 (1949).
- (240) Mulliken, Wakeman, and Gerry, *J. Am. Chem. Soc.*, 57, 1605-7 (1935).
- (241) Murat, *Ann. chim.*, [8], 16, 108-26 (1909).
- (242) Muset, *Bull. acad. roy. Belg., Classe sci.*, 1906, 775-89; *Chem. Abstr.*, 1, 1969 (1907).
- (243) Muskat and Herrman, *J. Am. Chem. Soc.*, 53, 252-60 (1931).
- (244) Nazarov and Elizarova, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1940, 189-94; *Chem. Abstr.*, 36, 741 (1942).
- (245) Nazarov and Torgov, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1946, 495-9; *Chem. Abstr.*, 42, 7735 (1948).
- (246) Nelken and Simonis, *Ber.*, 41, 986-9 (1908).
- (247) Nesmeyanov and Sazanova, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1941, 499-519; *Chem. Abstr.*, 37, 2723 (1943).
- (248) Newman and Smith, *J. Org. Chem.*, 13, 592-8 (1948).
- (249) Niemann, Benson, and Mead, *J. Org. Chem.*, 8, 397-404 (1943).
- (250) Noller and Adams, *J. Am. Chem. Soc.*, 48, 1074-80 (1926).
- (251) Noller and Adams, *J. Am. Chem. Soc.*, 48, 1080-9 (1926).
- (252) Nomura, *Bull. soc. chim.*, [4], 37, 1245-7 (1925).
- (253) Norris and Blake, *J. Am. Chem. Soc.*, 50, 1808-12 (1928).
- (254) Norris and Cortese, *J. Am. Chem. Soc.*, 49, 2640-50 (1927).
- (255) Norton and Hass, *J. Am. Chem. Soc.*, 58, 2147-50 (1936).

- (256) Oddo and Cambieri, *Gazz. chim. ital.*, 70, 559-66 (1940); *Chem. Abstr.*, 35, 1050 (1941).
- (257) Oddo and del Rosso, *Gazz. chim. ital.*, 41, 1, 273-94 (1910); *Chem. Zentr.*, 1911, 1, 1855.
- (258) Ou Kiun-Houo, *Ann. chim.*, [11], 13, 175-241 (1940).
- (259) Overberger, Saunders, Allen, and Gander, *Organic Syntheses*, 28, 28-30 (1948).
- (260) Overhoff and Proost, *Rec. trav. chim.*, 57, 179-84 (1938).
- (261) Pariselle, *Compt. rend.*, 148, 849-51 (1909); *Chem. Zentr.*, 1909, 1, 1744.
- (262) Pariselle, *Compt. rend.*, 154, 710-2 (1912); *Chem. Zentr.*, 1912, 1, 1441.
- (263) Pauly and Buttlar, *Ann.*, 383, 230-88 (1911).
- (264) Pel'kis and Pazenko, *Zapiski Inst. Khim.*, Akad. Nauk. U.R.S.R., *Inst. Khim.*, 6, Nos. 3-4, 311-39 (1940); *Chem. Abstr.*, 35, 2469 (1941).
- (265) Perlmann, Davidson, and Bogert, *J. Org. Chem.*, 1, 288-99 (1936).
- (266) Petrov and Kaplan, *J. Gen. Chem. (U.S.S.R.)*, 12, 99-103 (1942); *Chem. Abstr.*, 37, 1983 (1943).
- (267) Petrov and Kaplan, *Otdel Khim. Nauk. Izvest. Akad. Nauk. S.S.S.R.*, 1947, 295-308; *Chem. Abstr.*, 43, 1718 (1949).
- (268) Petrov and Karlik, *J. Gen. Chem. (U.S.S.R.)*, 11, 1100-3 (1941); *Chem. Abstr.*, 37, 4049 (1942).
- (269) Petrov and Ol'dekop, *J. Gen. Chem. (U.S.S.R.)*, 18, 859-64 (1948); *Chem. Abstr.*, 43, 107 (1949).
- (270) Petyunin, *Trudy Moskov. Med. Inst.*, 1940, No. 16, 7-12; *Khim. Referat. Zhur.*, 4, No. 9, 58 (1941); *Chem. Abstr.*, 38, 950 (1944).
- (271) Pexsters, *Bull. acad. roy. Belg., Classe sci.*, 1906, 796-802; *Chem. Zentr.*, 1907, 1, 1398.
- (272) Prévost, *Ann. chim.*, [10], 10, 147-81 (1928).
- (273) Proost and Wibaut, *Rec. trav. chim.*, 59, 971-7 (1940).
- (274) Prout, Cason, and Ingersoll, *J. Am. Chem. Soc.*, 70, 298-305 (1948).
- (275) Pschorr and Einbeck, *Ber.*, 38, 2067-77 (1905).
- (276) Quelet, *Compt. rend.*, 186, 236-8 (1928).
- (277) Quelet, *Bull. soc. chim.*, [4], 45, 75-97 (1929).
- (278) Quelet, *Bull. soc. chim.*, [4], 45, 255-74 (1929).
- (279) Quelet and Golse, *Compt. rend.*, 224, 661-3 (1947); *Chem. Abstr.*, 41, 4779 (1947).
- (280) Reif, *Ber.*, 39, 1603-4 (1906).
- (281) Reif, *Ber.*, 41, 2739-46 (1908).
- (282) Ritter and Russell, *J. Am. Chem. Soc.*, 58, 291-3 (1936).
- (283) Roberts and Young, *J. Am. Chem. Soc.*, 67, 148-50 (1945).
- (284) Rozanov, *J. Russ. Phys.-Chem. Soc.*, 61, 2313-8 (1929); *Chem. Abstr.*, 24, 3766 (1930).
- (285) Rupe, *Ann.*, 402, 149-86 (1914).
- (286) Rupe and Rinderknecht, *Ann.*, 442, 61-73 (1925).
- (287) Rupe and Spittgerber, *Ber.*, 40, 2813-7 (1907).
- (288) Sabatier and Mailhe, *Compt. rend.*, 139, 343-6 (1904); *J. Chem. Soc.*, 86, 1, 809 (1904); *Chem. Zentr.*, 1904, 11, 704.
- (289) Sabatier and Murat, *Compt. rend.*, 157, 1496-500 (1913); *Chem. Abstr.*, 8, 1088 (1914).
- (290) Sabatier and Murat, *Compt. rend.*, 158, 534-7 (1914); *Chem. Abstr.*, 8, 1751 (1914).
- (291) Sachs and Sachs, *Ber.*, 38, 511-7 (1905).
- (292) Sachs and Steinert, *Ber.*, 37, 1733-45 (1904).

- (293) Sah, *J. Chinese Chem. Soc.*, 13, 89-95 (1946); *Chem. Abstr.*, 41, 5869 (1947).
- (294) Salkind and Teterin, *Ber.*, 66B, 321-5 (1933).
- (295) Sand and Singer, *Ber.*, 35, 3170-87 (1902).
- (296) Savard and Hösöğüt, *Rev. faculté sci. univ. Istanbul*, [N.S.], 3, 164-73 (1938); *Chem. Abstr.*, 32, 5795 (1938).
- (297) Savariau, *Compt. rend.*, 146, 297-8 (1908); *Chem. Zentr.*, 1908, I, 1388.
- (298) Schmidlin and Garcia-Banús, *Ber.*, 45, 3193-203 (1912).
- (299) Schmidlin and Hodgson, *Ber.*, 41, 430-7 (1907).
- (300) Schmidlin and von Escher, *Ber.*, 45, 889-99 (1912).
- (301) Shurakowski, *J. Russ. Phys.-Chem. Soc.*, 41, 1687-94 (1910); *Chem. Zentr.*, 1910, I, 1144.
- (302) Simonis, Marben, and Mermod, *Ber.*, 38, 3981-5 (1905).
- (303) Smith and Sprung, *J. Am. Chem. Soc.*, 65, 1276-83 (1943).
- (304) Soc. pour l'ind. chim. à Bâle; Swiss Patent 232,887, Sept. 16, 1944 (Cl. 36 q); *Chem. Abstr.*, 43, P5403 (1949).
- (305) Sontag, *Ann. chim.*, [11], 1, 359-438 (1934).
- (306) Ssemenzow and Konjuchow-Dobryna, *J. Russ. Phys.-Chem. Soc.*, 43, 990-2 (1911); *Chem. Zentr.*, 1911, II, 1923.
- (307) Stedman and Stedman, *J. Chem. Soc.*, 1929, 609-17.
- (308) Stevens, *J. Am. Chem. Soc.*, 56, 1425 (1934).
- (309) Stevens, *J. Am. Chem. Soc.*, 57, 1112-7 (1935).
- (310) Stoermer and Friderici, *Ber.*, 41, 324-43 (1908).
- (311) Stohr, *Ber.*, 72B, 1138-9 (1939).
- (312) Tamele, Ott, Marple, and Hearne, *Ind. Eng. Chem.*, 33, 115-20 (1941).
- (313) Tarbell and Paulson, *J. Am. Chem. Soc.*, 64, 2842-4 (1942).
- (314) Tarbell and Sato, *J. Am. Chem. Soc.*, 68, 1091-4 (1946).
- (315) Tchoubar and Sackur, *Compt. rend.*, 207, 1105-6 (1938); *Chem. Abstr.*, 33, 2111 (1939).
- (316) Tiffeneau, *Ann. chim.*, [8], 10, 322-78 (1907).
- (317) Tiffeneau and Lévy, *Bull. soc. chim.*, [4], 49, 1738-53 (1931).
- (318) Tiffeneau, Lévy, and Kayser, *Compt. rend.*, 196, 1407-8 (1933).
- (319) Tiffeneau, Lévy, and Weill, *Bull. soc. chim.*, [4], 49, 1709-21 (1931).
- (320) Tiffeneau and Neuberg, *Compt. rend.*, 198, 2174-6 (1934).
- (321) Timmermans and Hennaut-Roland, *Anales soc. espñ. fís. quim.*, 27, 460-72 (1929); *Chem. Abstr.*, 24, 54 (1930).
- (322) Tomecko and Adams, *J. Am. Chem. Soc.*, 49, 522-30 (1927).
- (323) Tsatsas, *Ann. chim.*, [12], 1, 342-94 (1946).
- (324) Tschitschibabin, *Ber.*, 42, 3469-79 (1909).
- (325) Tschitschibabin, *J. Russ. Phys.-Chem. Soc.*, 4, 1116-7 (1910); *Chem. Zentr.*, 1910, I, 32.
- (326) Tuot, *Compt. rend.*, 202, 1339-40 (1936).
- (327) Tuot and Guyard, *Bull. soc. chim.*, [5], 14, 1087-96 (1947).
- (328) Turkiewicz, *Ber.*, 72B, 1060-3 (1938).
- (329) Urion, *Compt. rend.*, 194, 2311-3 (1932).
- (330) Ushakov and Kucherov, *J. Gen. Chem. (U.S.S.R.)*, 14, 1080-6 (1944); *Chem. Abstr.*, 40, 7185 (1946).
- (331) Ushakov and Kucherov, *J. Gen. Chem. (U.S.S.R.)*, 14, 1087-91 (1944); *Chem. Abstr.*, 40, 7186 (1946).
- (332) Van Gysegem, *Bull. acad. roy. Belg.*, 1906, 692-706; *Chem. Zentr.*, 1907, I, 529.
- (333) van Risseghem, *Bull. soc. chim. Belg.*, 35, 328-64 (1926).
- (334) van Risseghem, *Bull. soc. chim. Belg.*, 39, 349-68 (1930).

- (335) Vavon and Guédon, *Bull. soc. chim.*, [4], 47, 901-10 (1930).
- (336) Veibel, Lundqvist, Andersen, and Frederiksen, *Bull. soc. chim.*, [5], 6, 990-8 (1939).
- (337) Vène, *Ann. chim.*, [11], 10, 194-279 (1938).
- (338) Vène, *Bull. soc. chim.*, [5], 6, 692-7 (1939).
- (339) Venús-Danilova and Bol'shukhin, *J. Gen. Chem.* (U.S.S.R.), 9, 975-84 (1939); *Chem. Abstr.*, 33, 8595 (1939).
- (340) Venús-Danilova and Brichko, *J. Gen. Chem.* (U.S.S.R.), 17, 1549-58 (1947); *Chem. Abstr.*, 42, 2243 (1948).
- (341) Vernimmen, *Bull. soc. chim. Belg.*, 33, 96-101 (1924).
- (342) von Auwers and Treppmann, *Ber.*, 48, 1207-25 (1915).
- (343) von Auwers and Westermann, *Ber.*, 54B, 2993-9 (1921).
- (344) von Braun, *Ber.*, 44, 2867-81 (1911).
- (345) von Braun, Deutsch, and Schmatloch, *Ber.*, 45, 1246-63 (1912).
- (346) von Braun and Kirschbaum, *Ber.*, 52B, 1725-30 (1919).
- (347) Webster and Schaefer, *Proc. S. Dakota Acad. Sci.*, 19, 124-9 (1939); *Chem. Abstr.*, 34, 2784 (1940).
- (348) Weill, *Bull. soc. chim.*, [4], 49, 1795-806 (1931).
- (349) Werner and Bogert, *J. Org. Chem.*, 3, 578-87 (1939).
- (350) Whitby and Gallay, *Can. J. Research*, 6, 280-91 (1932); *Chem. Abstr.*, 26, 3479 (1932).
- (351) Whitmore and Badertscher, *J. Am. Chem. Soc.*, 55, 1559-67 (1933).
- (352) Whitmore and Church, *J. Am. Chem. Soc.*, 55, 1119-24 (1933).
- (353) Whitmore and Houk, *J. Am. Chem. Soc.*, 54, 3714-8 (1932).
- (354) Whitmore and Lewis, *J. Am. Chem. Soc.*, 64, 1618-9 (1942).
- (355) Whitmore and Lewis, *J. Am. Chem. Soc.*, 64, 2964-6 (1942).
- (356) Whitmore and Sloat, *J. Am. Chem. Soc.*, 64, 2968-70 (1942).
- (357) Whitmore, Sommer, Gold, and Van Strien, *J. Am. Chem. Soc.*, 69, 1551 (1947).
- (358) Whitmore, Whitaker, Mosher, Breivik, Wheeler, Miner, Sutherland, Wagner, Clapper, Lewis, Lux, and Popkin, *J. Am. Chem. Soc.*, 63, 643-54 (1941).
- (359) Wibaut, Hoog, Langedijk, Overhoff, and Smittenberg, *Rec. trav. chim.*, 58, 329-77 (1939).
- (360) Willstaedt, *Ber.*, 64B, 2693-5 (1931).
- (361) Wohl and Losanitsch, *Ber.*, 41, 3621-2 (1908).
- (362) Wohl and Roth, *Ber.*, 40, 212-8 (1907).
- (363) Wood and Scarf, *J. Soc. Chem. Ind.*, 42, 13-15T (1923).
- (364) Woods and Schwartzman, *J. Am. Chem. Soc.*, 70, 3394-6 (1948).
- (365) Woods and Schwartzman, *J. Am. Chem. Soc.*, 71, 1396-9 (1949).
- (366) Yamashita, *J. Chem. Soc. Japan*, 62, 1216-8 (1941); *Chem. Abstr.*, 41, 3070 (1947).
- (367) Young and Roberts, *J. Am. Chem. Soc.*, 67, 1040 (1945).
- (368) Young and Roberts, *J. Am. Chem. Soc.*, 68, 649-52 (1946).
- (369) Zal'kind and Kulikov, *J. Gen. Chem.* (U.S.S.R.), 15, 643-9 (1945); *Chem. Abstr.*, 40, 6061 (1946).
- (370) Zal'kind and Labuzov, *J. Gen. Chem.* (U.S.S.R.), 9, 1525-32 (1939); *Chem. Abstr.*, 34, 2788 (1940).
- (371) Zelinsky, *Ber.*, 41, 2628-9 (1908).
- (372) Ziegler, *Ber.*, 54B, 737-40 (1921).
- (373) Ziegler and Tiemann, *Ber.*, 55B, 3406-16 (1922).
- (374) von Doering and Beringer, *J. Am. Chem. Soc.*, 71, 2221-6 (1949).
- (375) Pickard and Kenyon, *J. Chem. Soc.*, 99, 45-72 (1911).
- (376) Oddo and Toffoli, *Gazz. chim. ital.*, 64, 359-63 (1934); *Chem. Abstr.*, 28, 6436 (1934).

- (377) Venús-Danilova and Brichko, *J. Gen. Chem.* (U.S.S.R.), 17, 1849-57 (1947); *Chem. Abstr.*, 42, 4160 (1948).
- (378) Schiemann and Pillarsky, *Ber.*, 64B, 1340-5 (1931).
- (379) Hébert, *Bull. soc. chim.*, [4], 27, 45-55 (1920).
- (380) Klages, *Ber.*, 35, 2649-52 (1902).
- (381) Khaletzkiĭ, *J. Gen. Chem.* (U.S.S.R.), 6, 1-14 (1936); *Chem. Abstr.*, 30, 4844 (1936).
- (382) Gray and Fuson, *J. Am. Chem. Soc.*, 56, 739-41 (1934).
- (383) Sachs and Appenzeller, *Ber.*, 41, 91-108 (1908).
- (384) van Dorp and Arens, *Nature*, 160, 189 (1947).
- (385) Faworsky, *J. prakt. Chem.*, [2], 88, 641-98 (1913).
- (386) Heilbron, Jones, and Weedon, *J. Chem. Soc.*, 1944, 140-1.
- (387) Heilbron, Johnson, Jones, and Raphael, *J. Chem. Soc.*, 1943, 265-8.
- (388) Mosher and La Combe, *J. Am.-Chem. Soc.*, 72, 4991-4 (1950).
- (389) Guest, *J. Am. Chem. Soc.*, 47, 860-3 (1925).
- (390) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 42, 1083 (1910); *Bull. soc. chim.*, [4], 10, 1148 (1911).
- (391) Lespieau, *Bull. soc. chim.*, [4], 39, 991-4 (1926).
- (392) Zal'kind and Gverdtsiteli, *J. Gen. Chem.* (U.S.S.R.), 9, 971-4 (1939); *Chem. Abstr.*, 33, 8569 (1939).
- (393) Lespieau and Lombard, *Bull. soc. chim.*, [4], 39, 369-73 (1935).
- (394) Heilbron, Jones, Lacey, McCombie, and Raphael, *J. Chem. Soc.*, 1945, 77-81.
- (395) Teterin and Ivanov, *J. Gen. Chem.* (U.S.S.R.), 7, 1629-31 (1937); *Chem. Abstr.*, 31, 8305 (1937).
- (396) Marvel and Schertz, *J. Am. Chem. Soc.*, 65, 2054-8 (1943).
- (397) Heilbron, Jones, and Raphael, *J. Chem. Soc.*, 1943, 268-70.
- (398) Cymerman, Heilbron, Johnson, and Jones, *J. Chem. Soc.*, 1944, 144-4.
- (399) Marvel and Williams, *J. Am. Chem. Soc.*, 61, 2714-6 (1939).
- (400) Heilbron, Jones, and Raphael, *J. Chem. Soc.*, 1944, 136-9.
- (401) Brooks, *J. Am. Chem. Soc.*, 66, 1295-7 (1944).
- (402) Isler, Huber, Ronco, and Kofler, *Helv. Chim. Acta*, 30, 1911-27 (1947).
- (403) Cymerman, Heilbron, Jones, and Lacey, *J. Chem. Soc.*, 1946, 500-3.
- (404) Heilbron, *J. Chem. Soc.*, 1948, 386-93.
- (405) Victoria, *Rec. trav. chim.*, 24, 265-96 (1905).
- (406) Barré and Repentigny, *Can. J. Research*, 27B, 716-20 (1949).
- (407) Reynolds, *Am. Chem. J.*, 44, 305-31 (1910).
- (408) Sabatier and Mailhe, *Ann. chim.*, [8], 10, 527-74 (1907).
- (409) Letzinger and Schnizer, *J. Org. Chem.*, 16, 704-7 (1951).
- (410) Newman, *J. Am. Chem. Soc.*, 62, 2295-300 (1940).
- (411) Freedman and Becker, *J. Org. Chem.*, 16, 1701-11 (1951).
- (412) Gmitter and Benton, *J. Am. Chem. Soc.*, 72, 4586-9 (1950).
- (413) Robinson, *J. Chem. Soc.*, 1936, 80.
- (414) Arnold and Coyner, *J. Am. Chem. Soc.*, 66, 1543-5 (1944).
- (415) Gaylord and Becker, *J. Org. Chem.*, 15, 305-16 (1950).
- (416) Oddo, *Gazz. chim. ital.*, 41,1, 273-94 (1911); *Chem. Abstr.*, 5, 2639 (1911).
- (417) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 34, 96-8 (1902); *Bull. soc. chim.*, [3], 28, 920 (1902).
- (418) Dupont, *Compt. rend.*, 149, 1381-3 (1910); *Chem. Abstr.*, 4, 1479 (1910).
- (419) Dupont, *Compt. rend.*, 150, 1121-3 (1910); *Chem. Abstr.*, 4, 2096 (1910).
- (420) Dupont, *Compt. rend.*, 153, 275-7 (1911); *Chem. Abstr.*, 5, 3408 (1911).
- (421) Dupont, *Compt. rend.*, 158, 714-6 (1914); *Chem. Zentr.*, 1914,1, 1503.
- (422) Dupont, *Bull. soc. chim.*, [4], 15, 604-8 (1914).

- (423) Grard, *Ann. chim.*, [10], 13, 336-81 (1930).
- (424) Yur'ev, Voronkov, Gragerov, and Ya, *J. Gen. Chem.* (U.S.S.R.), 18, 1804-10 (1948); *Chem. Abstr.*, 43, 3818 (1949).
- (425) Elderfield, Pitt, and Wempen, *J. Am. Chem. Soc.*, 72, 1334-45 (1950).
- (426) Hiers and Adams, *J. Am. Chem. Soc.*, 48, 2385-95 (1926).
- (427) Szmant, Anzenberger, and Hartle, *J. Am. Chem. Soc.*, 72, 1419-20 (1950).
- (428) Godchot, Bedos, and Cauquil, *Bull. soc. chim.*, [4], 43, 521-2 (1928).
- (429) Plate, Shafran, and Batuev, *J. Gen. Chem.* (U.S.S.R.), *Chem. Abstr.*, 44, 7785 (1950).
- (430) Dice, Watkins, and Schuman, *J. Am. Chem. Soc.*, 72, 1738-40 (1950).
- (431) Schinz and Simon, *Helv. Chim. Acta*, 28, 774-80 (1945).
- (432) Glattfeld and Cameron, *J. Am. Chem. Soc.*, 49, 1043-8 (1927).
- (433) Kayser, *Ann. chim.*, [11], 6, 145-248 (1936).
- (434) Frank, Adams, Allen, Gander, and Smith, *J. Am. Chem. Soc.*, 68, 1365-8 (1946).
- (435) Sobotka and Stynler, *J. Am. Chem. Soc.*, 72, 5139-43 (1950).
- (436) McBee, Pierce, and Higgins, *J. Am. Chem. Soc.*, 74, 1736-7 (1952).
- (437) Field, *J. Am. Chem. Soc.*, 74, 3919-21 (1952).
- (438) Lawrence and Shelton, *Ind. Eng. Chem.*, 42, 136-40 (1950).
- (439) Inhoffen, Bohlman, and Reinefeld, *Chem. Ber.*, 82, 313-6 (1949).
- (440) Godchot and Cauquil, *Bull. soc. chim.*, [4], 43, 520-1 (1928).
- (441) Carré, *Bull. soc. chim.*, [4], 5, 486-9 (1909).
- (442) Carré, *Bull. soc. chim.*, [4], 7, 841-6 (1910).
- (443) Gaertner, *J. Am. Chem. Soc.*, 73, 3934-7 (1951).
- (444) Gaertner, *J. Am. Chem. Soc.*, 74, 766-7 (1952).
- (445) Gaertner, *J. Am. Chem. Soc.*, 74, 2185-8 (1952).
- (446) Marshall, *Proc. Chem. Soc.*, 30, 13-4 (1914); *J. Chem. Soc.*, 105, 527-34 (1914).
- (447) Marshall, *J. Chem. Soc.*, 107, 509-23 (1915).
- (448) Mousseron and Du, *Bull. soc. chim.*, [5], 15, 91-6 (1948).
- (449) Prévost, Gaudemar, and Honigberg, *Compt. rend.*, 230, 1186-8 (1950); *Chem. Abstr.*, 45, 1497 (1951).
- (450) Newman and Wotiz, *J. Am. Chem. Soc.*, 71, 1292-7 (1949).
- (451) Sherman and Amstutz, *J. Am. Chem. Soc.*, 72, 2195-9 (1950).
- (452) Young and Siegel, *J. Am. Chem. Soc.*, 66, 354-8 (1944).
- (453) Siegel, Coburn, and Levering, *J. Am. Chem. Soc.*, 73, 3163-5 (1951).
- (454) Siegel, Boyer, and Joy, *J. Am. Chem. Soc.*, 73, 3237-40 (1951).

TABLE VI-XVIII
REACTIONS OF GRIGNARD REAGENTS WITH KETENES AND ACYCLIC KETONES

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₂O			
H ₂ C=CO	CH ₃ MgI	(CH ₃) ₂ CO (trace); brown resin	89
H ₂ C=CO	C ₂ H ₅ MgCl*	CH ₃ COC ₂ H ₅ (36.6%)	1
H ₂ C=CO	C ₂ H ₅ MgBr	CH ₃ COC ₂ H ₅ (trace)	2
H ₂ C=CO	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ CO- <i>n</i> -C ₃ H ₇ (34.2-35.6%)	2
H ₂ C=CO	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ CO- <i>n</i> -C ₄ H ₉ (32.7%)	2
H ₂ C=CO	C ₆ H ₅ MgBr	CH ₃ COC ₆ H ₅ (30-35%)	1
C₃H₃OCl₃			
Cl ₃ CCOCH ₃	CH ₃ MgBr	Cl ₃ C(CH ₃) ₂ COH	3
C₃H₃OF₃			
CF ₃ COCH ₃ (0.2-0.3 mole)	C ₂ H ₅ MgI (0.4-0.6 mole)	CF ₃ (CH ₃)(C ₂ H ₅)COH (78.9%); CF ₃ (CH ₃)CHOH (13.9%)	654
C₃H₄OCl₂			
(ClCH ₂) ₂ CO	CH ₃ MgBr	CH ₃ (ClCH ₂) ₂ COH	3
(ClCH ₂) ₂ CO	H ₂ C=CHCH ₂ MgBr	H ₂ C=CHCH ₂ (ClCH ₂) ₂ COH (36%)	4
C₃H₄O₃			
HO ₂ CCOCH ₃ (20 g.)	4-CH ₃ C ₆ H ₄ MgBr (116 g. C ₇ H ₇ Br)	DL-HO ₂ C(CH ₃)(4-CH ₃ C ₆ H ₄)COH (15 g.)	5
HO ₂ CCOCH ₃ (11.5 g.)	4-CH ₃ OC ₆ H ₄ MgBr (66.5 g. C ₇ H ₇ BrO)	DL-HO ₂ C(CH ₃)(4-CH ₃ OC ₆ H ₄)COH (10.3 g.)	5
C₃H₅OBr			
BrCH ₂ COCH ₃	CH ₃ MgBr (2 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (18%)	6
BrCH ₂ COCH ₃	CH ₃ MgI (2 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (12%)	6

*The use of C₂H₅MgBr is said to lead to considerable ketene dimerization.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₇OCl			
ClCH ₂ COCH ₃	CH ₃ MgBr	ClCH ₂ (CH ₃) ₂ COH	2
ClCH ₂ COCH ₃	CH ₃ MgBr (2 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH	7
ClCH ₂ COCH ₃	CH ₃ MgX*	ClCH ₂ (CH ₃) ₂ COH; CH ₃ (<i>i</i> -C ₃ H ₇)CHOH	9
ClCH ₂ COCH ₃	CH ₃ Mgl	ClCH ₂ (CH ₃) ₂ COH (<i>ca.</i> 20%)	8
ClCH ₂ COCH ₃	(≡CMgBr) ₂	[≡CC(CH ₃)(CH ₂ Cl)OH] ₂	621
ClCH ₂ COCH ₃	C ₂ H ₅ MgCl	1,2-Epoxy-2-methylbutane (60%)	9
ClCH ₂ COCH ₃	C ₂ H ₅ MgBr	ClCH ₂ (CH ₃)(C ₂ H ₅)COH (72%) [†]	8
ClCH ₂ COCH ₃	C ₂ H ₅ MgBr	ClCH ₂ (CH ₃)(C ₂ H ₅)COH; C ₂ H ₅ (<i>s</i> -C ₄ H ₉)CHOH	9
ClCH ₂ COCH ₃	C ₂ H ₅ MgBr	1,2-Epoxy-2-methylbutane (68%); C ₂ H ₅ (<i>s</i> -C ₄ H ₉)CHOH ("small am'ts")	10
ClCH ₂ COCH ₃	H ₂ C=CHCH ₂ MgBr	ClCH ₂ (CH ₃)(H ₂ C=CHCH ₂)COH (55%)	4
ClCH ₂ COCH ₃	(<i>i</i> -C ₃ H ₁₁) ₂ Mg	CH ₃ (<i>i</i> -C ₃ H ₁₁)(<i>i</i> -C ₆ H ₁₃)COH	11
ClCH ₂ COCH ₃	C ₆ H ₅ MgBr	ClCH ₂ (CH ₃)(C ₆ H ₅)COH	8
ClCH ₂ COCH ₃	C ₆ H ₅ MgBr	CH ₃ COCH ₂ C ₆ H ₅	12, 13
ClCH ₂ COCH ₃ (32 g.)	4-CH ₃ C ₆ H ₄ MgBr (86 g. C ₇ H ₇ Br)	CH ₃ COCH ₂ C ₆ H ₄ -4-CH ₃ (29 g.)	14
ClCH ₂ COCH ₃	<i>n</i> -C ₃ H ₁₁ C≡CMgBr	ClCH ₂ (CH ₃)(<i>n</i> -C ₃ H ₁₁ C≡C)COH	15
ClCH ₂ COCH ₃	2-C ₆ H ₅ C ₆ H ₄ Mgl	ClCH ₂ (CH ₃)(2-C ₆ H ₅ C ₆ H ₄)COH	16
ClCH ₂ COCH ₃ (115 g., 1.25 mole)	RC≡CMgBr [†] (1.25 mole)	ClCH ₂ (CH ₃)(RC≡C)COH [†] (167 g.)	97
C₃H₅O₂N			
HON=CHCOCH ₃ (17.5 g.)	C ₂ H ₅ MgBr (87 g. C ₂ H ₅ Br)	HON=CH(CH ₃)(C ₂ H ₅)COH (50%); CH ₃ (C ₂ H ₅) ₂ COH; CH ₃ COC ₂ H ₅	17
HON=CHCOCH ₃ (17.5 g.)	<i>n</i> -C ₄ H ₉ MgBr (129.6 g. C ₄ H ₉ Br)	HON=CH(CH ₃)(<i>n</i> -C ₄ H ₉)COH (50%); CH ₃ CO- <i>n</i> -C ₄ H ₉	17

*X = Br, I.

[†]Claim subsequently modified by Fourneau and Tiffeneau (9).[†]R = 1-Cyclohexenyl.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₃H₅O₂N (<i>cont.</i>)			
HON=CHCOCH ₃ (29 g.)	C ₆ H ₅ MgBr (210 g. C ₆ H ₅ Br)	HON=CH(CH ₃)(C ₆ H ₅)COH (36%); CH ₃ COC ₆ H ₅	17
C₃H₆O			
(CH ₃) ₂ CO	CH ₃ MgI	(CH ₃) ₃ COH (70%)	18
(CH ₃) ₂ CO	(≡CMgBr) ₂	[≡CC(CH ₃) ₂ OH] ₂ (80%)	19,20, 21,22, 118,628
(CH ₃) ₂ CO (10.6 g.) + (C ₆ H ₅) ₂ CO (54.6 g.)	(≡CMgBr) ₂	[≡CC(CH ₃) ₂ OH] ₂ (2.5 g.); [≡CC(C ₆ H ₅) ₂ OH] ₂ (34.0 g.); HO(CH ₃) ₂ CC≡CC(C ₆ H ₅) ₃ OH	23
(CH ₃) ₂ CO	C ₂ H ₅ MgCl	C ₂ H ₅ (CH ₃) ₂ COH (70%)	10
(CH ₃) ₂ CO (45 g.)	C ₂ H ₅ MgBr (81 g. C ₂ H ₅ Br)	C ₂ H ₅ (CH ₃) ₂ COH (<i>ca.</i> 25 g.)	24
(CH ₃) ₂ CO	C ₂ H ₅ I + Mg*	C ₂ H ₅ (CH ₃) ₂ COH	609
(CH ₃) ₂ CO	CH ₃ C≡CMgBr	CH ₃ C≡C(CH ₃) ₂ COH (95%)	36
(CH ₃) ₂ CO	H ₂ C=CHCH ₂ MgBr	H ₂ C=CHCH ₂ (CH ₃) ₂ COH (70%, crude; 53%, purified)	25,26, 27,28, 29,30
(CH ₃) ₂ CO (2.3 moles)	<i>n</i> -C ₃ H ₇ MgBr (2.5 moles C ₃ H ₇ Br)	<i>n</i> -C ₃ H ₇ (CH ₃) ₂ COH (159 g.)	31,11, 32,33, 34,35
(CH ₃) ₂ CO	<i>n</i> -C ₃ H ₇ MgI	<i>n</i> -(C ₃ H ₇)(CH ₃) ₂ COH (contam'd with I comp'ds)	32
(CH ₃) ₂ CO	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (CH ₃) ₂ COH	37,11
(CH ₃) ₂ CO	H ₂ C=CHC≡CMgBr	H ₂ C=CHC≡C(CH ₃) ₂ OH (53%)	38,39,40
(CH ₃) ₂ CO	2-Thienyl-MgI	α-C ₄ H ₃ S(CH ₃) ₂ COH; α-C ₄ H ₃ S(CH ₃)C=CH ₂	41
(CH ₃) ₂ CO	C ₂ H ₅ C≡CMgBr	C ₂ H ₅ C≡C(CH ₃) ₂ COH	42

*Without solvent (other than the reactants).

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₆O (<i>cont.</i>)			
(CH ₃) ₂ CO (5.8 g.)	C ₂ H ₅ OC≡CMgBr (7.5 g. C ₂ H ₅ OC≡CH)	C ₂ H ₅ OC≡C(CH ₃) ₂ COH (63%)	43
(CH ₃) ₂ CO	(CH ₂) ₄ CHMgBr	(CH ₂) ₄ CH(CH ₃) ₂ COH + (CH ₂) ₄ C=CH ₂ (aggregating 45%)	69
(CH ₃) ₂ CO	H ₂ C=C(CH ₃)CH ₂ Cl + Mg	H ₂ C=C(CH ₃)CH ₂ (CH ₃) ₂ COH (59%); [H ₂ C=C(CH ₃)CH ₂ —] ₂ (37%)	44
(CH ₃) ₂ CO	Butenyl-MgBr*	H ₂ C=CCH(CH ₃)C(CH ₃) ₂ OH (<i>ca.</i> 81%); [<i>no</i> CH ₃ CH=CHCH ₂ (CH ₃) ₂ COH]	45
(CH ₃) ₂ CO	<i>n</i> -C ₄ H ₉ MgCl	<i>n</i> -C ₄ H ₉ (CH ₃) ₂ COH (70%)	614
(CH ₃) ₂ CO (6.0 moles)	<i>n</i> -C ₄ H ₉ MgBr (6.5 moles C ₄ H ₉ Br)	<i>n</i> -C ₄ H ₉ (CH ₃) ₂ COH (640 g., 92%)	46,31,33
(CH ₃) ₂ CO	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ (CH ₃) ₂ COH (73.6%); (CH ₃) ₂ CHOH (6.6%); [HO(CH ₃) ₂ C—] ₂ (5.0%); C ₇ H ₁₄ (41%); C ₈ H ₁₈ (6.0%); C ₄ H ₈ (7.9%)	49
(CH ₃) ₂ CO	<i>i</i> -C ₄ H ₉ MgBr	<i>i</i> -C ₄ H ₉ (CH ₃) ₂ COH (54%)	46,34,50
(CH ₃) ₂ CO	<i>i</i> -C ₄ H ₉ MgI	<i>i</i> -C ₄ H ₉ (CH ₃) ₂ COH	51
(CH ₃) ₂ CO	<i>s</i> -C ₄ H ₉ MgBr	<i>s</i> -C ₄ H ₉ (CH ₃) ₂ COH	46,31,35
(CH ₃) ₂ CO†	<i>t</i> -C ₄ H ₉ MgCl	<i>t</i> -C ₄ H ₉ (CH ₃) ₂ COH (28%)	46,52
(CH ₃) ₂ CO	<i>t</i> -C ₄ H ₉ MgI	<i>t</i> -C ₄ H ₉ (CH ₃) ₂ COH (traces only); (CH ₃) ₂ C=CH	18
(CH ₃) ₂ CO	H ₂ C=C(CH ₃)C≡CMgBr	H ₂ C=C(CH ₃)C≡C(CH ₃) ₂ COH (58%)	40
(CH ₃) ₂ CO	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₅ H ₁₁ (CH ₃) ₂ COH (63%)	33
(CH ₃) ₂ CO	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₅ H ₁₁ (CH ₃) ₂ COH (46%); CH ₃ COCH=CH(CH ₃) ₂ ; [(CH ₃) ₂ C=CH] ₂ CO	18,54,55
(CH ₃) ₂ CO	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CH(CH ₃) ₂ COH	58,59
(CH ₃) ₂ CO	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ (CH ₃) ₂ COH	60

*From 80% CH₃CH=CHCH₂Br, 20% CH₃(H₂C=CH)CHBr.

†Edgar *et al.* (46) have emphasized the necessity for the use of acetone of high purity to avoid condensation, with negligible carbinol formation.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₆O (<i>cont.</i>)			
(CH ₃) ₂ CO	C ₆ H ₅ CH ₂ MgBr	C ₆ H ₅ CH ₂ (CH ₃) ₂ COH	18,61
(CH ₃) ₂ CO	2-,3-, or 4-CH ₃ C ₆ H ₄ MgBr	2-,3-, or 4-CH ₃ C ₆ H ₄ (CH ₃) ₂ COH	62
(CH ₃) ₂ CO	4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ (CH ₃) ₂ COH	63
(CH ₃) ₂ CO	C ₆ H ₅ C≡CMgX	C ₆ H ₅ C≡C(CH ₃) ₂ COH (95%)	64
(CH ₃) ₂ CO	C ₆ H ₅ C≡CMgBr	C ₆ H ₅ C≡C(CH ₃) ₂ COH (55%)	65
(CH ₃) ₂ CO	C ₆ H ₅ OC≡CMgBr	C ₆ H ₅ OC≡C(CH ₃) ₂ COH (63%); C ₆ H ₅ OH	66
(CH ₃) ₂ CO	2-Benzothiazolyl-CH ₂ MgBr	C ₇ H ₄ NSCH ₂ (CH ₃) ₂ COH	385
(CH ₃) ₂ CO	C ₆ H ₅ (CH ₂) ₂ MgBr	C ₆ H ₅ CH ₂ CH ₂ (CH ₃) ₂ COH	67,68
(CH ₃) ₂ CO	2-CH ₃ C ₆ H ₄ CH ₂ MgBr	2-CH ₃ C ₆ H ₄ CH ₂ (CH ₃) ₂ COH	655
(CH ₃) ₂ CO	3-CH ₃ C ₆ H ₄ CH ₂ MgBr (185 g. C ₈ H ₉ Br)	3-CH ₃ C ₆ H ₄ CH ₂ (CH ₃) ₂ COH (18-20 g.)	655
(CH ₃) ₂ CO	<i>n</i> -C ₈ H ₁₇ MgBr	<i>n</i> -C ₈ H ₁₇ (CH ₃) ₂ COH	48
(CH ₃) ₂ CO	1-Indenyl-MgBr	1-C ₉ H ₇ (CH ₃) ₂ COH (80%)	69
(CH ₃) ₂ CO	2-Methylindolyl-MgBr	2,2-Bis-(2-methyl-3-indolyl)propane	70
(CH ₃) ₂ CO	C ₆ H ₅ (CH ₂) ₃ MgBr	C ₆ H ₅ (CH ₂) ₃ C(CH ₃) ₂ OH (51%)	71
(CH ₃) ₂ CO (7.5 g.)	1-C ₁₀ H ₇ MgBr (25 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ (CH ₃) ₂ COH (21.6 g.)	72
(CH ₃) ₂ CO	CH ₃ (C ₆ H ₅)CH(CH ₂) ₂ MgBr	CH ₃ (C ₆ H ₅)CHCH ₂ CH ₂ (CH ₃) ₂ COH	73
(CH ₃) ₂ CO	3-CH ₃ C ₆ H ₄ (CH ₂) ₃ MgBr	3-CH ₃ C ₆ H ₄ (CH ₂) ₃ C(CH ₃) ₂ OH;	71
(CH ₃) ₂ CO	CH ₃ (C ₆ H ₅)N(CH ₂) ₃ MgBr	CH ₃ (C ₆ H ₅)N(CH ₂) ₃ C(CH ₃) ₂ OH;	73
		CH ₃ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅)N	
(CH ₃) ₂ CO	α -Camphoryl-MgBr*	α -C ₁₀ H ₁₅ O(CH ₃) ₂ COH (75-80%)	74,75
(CH ₃) ₂ CO	(CH ₃) ₅ C ₆ MgCl	(CH ₃) ₅ C ₆ (CH ₃) ₂ COH	76
(CH ₃) ₂ CO	(CH ₃) ₅ C ₆ MgBr	(CH ₃) ₅ C ₆ (CH ₃) ₂ COH (<i>ca.</i> 47%)	77
(CH ₃) ₂ CO	(CH ₃) ₅ C ₆ MgBr	(CH ₃) ₅ C ₆ (CH ₃) ₂ COH (25%); (CH ₃) ₅ C ₆ C(CH ₃)=CH ₂	78

*It seems possible (even probable) that this "Grignard reagent" is in fact an enolate.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₈O (<i>cont.</i>)			
(CH ₃) ₂ CO	2,4,5-(CH ₃) ₃ -3,6-(CH ₃ O) ₂ C ₆ (CH ₂) ₂ MgCl	2,4,5-(CH ₃) ₃ -3,6-(CH ₃ O) ₂ C ₆ (CH ₂) ₂ C(CH ₃) ₂ OH	79,80
(CH ₃) ₂ CO (6.5 g.)	9-Phenanthryl-MgBr (25.7 ml. C ₁₄ H ₉ Br)	9-C ₁₄ H ₉ (CH ₃) ₂ COH (yielding 9.2 g. olefin)	617
(CH ₃) ₂ CO	(C ₆ H ₅) ₃ CMgCl	"Passive"	81
C₃H₆O₂			
CH ₃ COCH ₂ OH	C ₂ H ₅ MgI (2 equiv.)	HOCH ₂ (CH ₃)(C ₂ H ₅)COH (> 50%)	82
C₄H₃OF₅			
CH ₃ COC ₂ F ₅ (0.2-0.3 mole)	C ₂ H ₅ MgI (0.4-0.6 mole)	CH ₃ (C ₂ F ₅)(C ₂ H ₅)COH (41.6%); CH ₃ (C ₂ F ₅)CHOH (44.5%)	654
C₄H₅OCl			
CH ₃ COCH=CHCl (20 g.)	CH ₃ MgBr (7 g. Mg)	ClCH=CH(CH ₃) ₂ COH (11 g.)	629
CH ₃ COCH=CHCl (52 g.)	H ₂ C=CHC≡CMgBr (52 g. C ₄ H ₄)	CH ₃ (ClCH=CH)(H ₂ C=CHC≡C)COH (67 g., 85%)	629
CH ₃ COCH=CHCl (42 g.)	<i>n</i> -C ₄ H ₉ C≡CMgBr (55 g. C ₆ H ₁₀)	CH ₃ (ClCH=CH)(<i>n</i> -C ₄ H ₉ C≡C)COH (69.9 g., 95%)	629
C₄H₆O			
CH ₃ COCH=CH ₂ (17.5 g.)	<i>n</i> -C ₄ H ₉ C≡CMgBr (24.0 g. <i>n</i> -C ₄ H ₉ C≡CH)	CH ₃ (H ₂ C=CH)(<i>n</i> -C ₄ H ₉ C≡C)COH (19.5 g.)	83
CH ₃ COCH=CH ₂	RC≡CMgBr*	CH ₃ (H ₂ C=CH)(RC≡C)COH* (45-50%)	84

*R = 1-Cyclohexenyl.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₆O₂			
(CH ₃ CO—) ₂	(≡CMgBr) ₂	HO(CH ₃)(HC≡C)COCH ₃	85
(CH ₃ CO—) ₂	H ₂ C=CHCH ₂ Br + Mg	[—C(OH)(CH ₃)CH ₂ CH=CH ₂] ₂ (ca. 10–16%)	86
(CH ₃ CO—) ₂	BrMg(CH ₂) ₅ MgBr	1,2-Dimethylcycloheptane-1,2-diol.	87
(CH ₃ CO—) ₂ (0.1 mole)	4-CH ₃ C ₆ H ₄ MgBr (0.25 mole)	[HO(CH ₃)(4-CH ₃ C ₆ H ₄)C—] ₂ , m.p. 136–137° ("small yield")	88
C₄H₇OCl			
ClCH ₂ COC ₂ H ₅	C ₂ H ₅ MgBr	ClCH ₂ (C ₂ H ₅) ₂ COH; C ₂ H ₅ CH(OH)CH(C ₂ H ₅) ₂ (?)	9
ClCH ₂ COC ₂ H ₅	<i>n</i> -C ₅ H ₁₁ C≡CMgBr	ClCH ₂ (C ₂ H ₅)(<i>n</i> -C ₅ H ₁₁ C≡C)COH	15
CH ₃ COCHClCH ₃	CH ₃ MgBr	CH ₃ CHCl(CH ₃) ₂ COH	9
CH ₃ COCHClCH ₃	C ₂ H ₅ MgBr	CH ₃ (CH ₃ CHCl)(C ₂ H ₅)COH	8,9
C₄H₇O₂N			
CH ₃ COC(=NOH)CH ₃ (15.2 g.)	CH ₃ MgI (64.0 g. CH ₃ I)	(CH ₃) ₂ C(OH)C(=NOH)CH ₃ (57%)	17,90
CH ₃ COC(=NOH)CH ₃ (20.2 g.)	<i>n</i> -C ₄ H ₉ MgBr (109.6 g. C ₄ H ₉ Br)	CH ₃ (<i>n</i> -C ₄ H ₉)C(OH)C(=NOH)CH ₃ (66%)	17
CH ₃ CO(C=NOH)CH ₃	4-CH ₃ C ₆ H ₄ MgBr	CH ₃ (4-CH ₃ C ₆ H ₄)C(OH)C(=NOH)CH ₃ (83%)	17
CH ₃ COC(=NOH)CH ₃ (25.3 g.)	<i>n</i> -C ₈ H ₁₇ MgBr (193.0 g. C ₈ H ₁₇ Br)	CH ₃ (<i>n</i> -C ₈ H ₁₇)C(OH)C(=NOH)CH ₃ (65%)	17
C₄H₈O			
CH ₃ COC ₂ H ₅	(≡CMgBr) ₂ (excess)	[≡CC(OH)(CH ₃)C ₂ H ₅] ₂ (ca. quant.)	22,21,118
CH ₃ COC ₂ H ₅	(≡CMgBr) ₂ + HC≡CMgBr	CH ₃ (HC≡C)(C ₂ H ₅)COH (6%); [≡CC(OH)(CH ₃)C ₂ H ₅] ₂ (65%)	91
CH ₃ COC ₂ H ₅ (2.4 moles)	C ₂ H ₅ MgBr (2.5 moles C ₂ H ₅ Br)	CH ₃ (C ₂ H ₅) ₂ COH (67%)	38,33,35, 47,92, 93
CH ₃ COC ₂ H ₅	CH ₃ C≡CMgBr	CH ₃ (C ₂ H ₅)(CH ₃ C≡C)COH (70%)	94

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₈O (<i>cont.</i>)			
CH ₃ COC ₂ H ₅ (156.0 g.)	H ₂ C=CHCH ₂ Cl (200.0 g.) + Mg (62.5 g.)	CH ₃ (C ₂ H ₅)(H ₂ C=CHCH ₂)COH (154.0 g., 52%)	95
CH ₃ COC ₂ H ₅	H ₂ C=CHCH ₂ MgBr	CH ₃ (C ₂ H ₅)(H ₂ C=CHCH ₂)COH (84%, crude)	25, 95
CH ₃ COC ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₃ H ₇)COH (64%)	46, 55
CH ₃ COC ₂ H ₅	<i>i</i> -C ₃ H ₇ MgCl	CH ₃ (C ₂ H ₅)(<i>i</i> -C ₃ H ₇)COH (28%); ketol (30%)	96
CH ₃ COC ₂ H ₅	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ (C ₂ H ₅)(<i>i</i> -C ₃ H ₇)COH	93
CH ₃ COC ₂ H ₅	2-Thienyl-MgI	CH ₃ (C ₂ H ₅)(α -C ₄ H ₃ S)COH; dehydr'n product	41
CH ₃ COC ₂ H ₅	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₄ H ₉)COH (65.5%)	38, 47, 98, 99
CH ₃ COC ₂ H ₅	<i>s</i> -C ₄ H ₉ MgBr	CH ₃ (C ₂ H ₅)(<i>s</i> -C ₄ H ₉)COH (25%)	38
CH ₃ COC ₂ H ₅	<i>i</i> -C ₃ H ₇ C \equiv CMgBr	CH ₃ (C ₂ H ₅)(<i>i</i> -C ₃ H ₇ C \equiv C)COH (76%)	94
CH ₃ COC ₂ H ₅ (72 g.)	<i>n</i> -C ₅ H ₁₁ MgBr (151 g. C ₅ H ₁₁ Br)	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₅ H ₁₁)COH (35 g.)	100, 54, 55, 101
CH ₃ COC ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ (C ₂ H ₅)(<i>i</i> -C ₅ H ₁₁)COH	54
CH ₃ COC ₂ H ₅ (72 g.)	DL- <i>s</i> -C ₄ H ₉ CH ₂ MgBr (151 g. C ₅ H ₁₁ Br)	CH ₃ (C ₂ H ₅)(<i>s</i> -C ₄ H ₉ CH ₂)COH (25 g.)	100
CH ₃ COC ₂ H ₅	<i>t</i> -C ₅ H ₁₁ MgBr	CH ₃ (C ₂ H ₅)(<i>t</i> -C ₅ H ₁₁)COH	102
CH ₃ COC ₂ H ₅	CH ₃ CH=C(CH ₃)C \equiv CMgBr	CH ₃ (C ₂ H ₅)[CH ₃ CH=C(CH ₃)C \equiv C]COH (79%)	94
CH ₃ COC ₂ H ₅	<i>n</i> -C ₄ H ₉ C \equiv CMgBr	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₄ H ₉ C \equiv C)COH (92%)	103
CH ₃ COC ₂ H ₅	<i>t</i> -C ₄ H ₉ C \equiv CMgBr	CH ₃ (C ₂ H ₅)(<i>t</i> -C ₄ H ₉ C \equiv C)COH (58%)	94
CH ₃ COC ₂ H ₅ (50 g.)	C ₆ H ₅ CH ₂ MgCl (100 g. C ₇ H ₇ Cl)	CH ₃ (C ₂ H ₅)(C ₆ H ₅ CH ₂)COH (83%)	650
CH ₃ COC ₂ H ₅	C ₆ H ₅ CH ₂ MgCl	CH ₃ (C ₂ H ₅)(C ₆ H ₅ CH ₂)COH; C ₆ H ₅ CH ₂ OH; (C ₆ H ₅ CH ₂ —) ₂	101, 68
CH ₃ COC ₂ H ₅	C ₆ H ₅ CH ₂ Cl + Mg	CH ₃ (C ₂ H ₅)(C ₆ H ₅ CH ₂)COH	104
CH ₃ COC ₂ H ₅	4-CH ₃ C ₆ H ₄ MgBr (51 g. C ₇ H ₇ Br)	CH ₃ (C ₂ H ₅)(4-CH ₃ C ₆ H ₄)COH (35 g., crude); (4-CH ₃ C ₆ H ₄ —) ₂	105

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₄H₈O (<i>cont.</i>)			
CH ₃ COC ₂ H ₅	C ₆ H ₅ C≡CMgBr	CH ₃ (C ₂ H ₅)(C ₆ H ₅ C≡C)COH (65%)	94
CH ₃ COC ₂ H ₅	2,4-(CH ₃) ₂ C ₆ H ₃ CH ₂ MgCl	CH ₃ (C ₂ H ₅)[2,4-(CH ₃) ₂ C ₆ H ₃ CH ₂]COH (>41%)*	106
CH ₃ COC ₂ H ₅	(CH ₃) ₅ C ₆ Br + CH ₃ I + Mg	(CH ₃) ₆ C ₆ ("a little"); (CH ₃) ₅ COCH ₃ (?) (40%)	78
CH ₃ COC ₂ H ₅	2,4,5-(CH ₃) ₃ -3,6- (CH ₃ O) ₂ C ₆ (CH ₂) ₂ MgCl	CH ₃ (C ₂ H ₅)[2,4,5-(CH ₃) ₃ -3,6- (CH ₃ O) ₂ C ₆ (CH ₂) ₂]COH†	80
C₅H₃OF₇			
CH ₃ CO- <i>n</i> -C ₃ F ₇ (0.2-0.3 mole)	C ₂ H ₅ MgI (0.4-0.6 mole)	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₃ F ₇)COH (18.0%); CH ₃ (<i>n</i> -C ₃ F ₇)CHOH (61.6%)	654
C₅H₆O₃			
(CH ₃ CO) ₂ CO	CH ₃ MgBr	[HO(CH ₃) ₂ C] ₂ CO	107
C₅H₈O			
CH ₃ COCH ₂ CH=CH ₂	CH ₃ MgI	H ₂ C=CHCH ₂ (CH ₃) ₂ COH (80%)	134, 135
CH ₃ COCH ₂ CH=CH ₂ (37 g.)	<i>n</i> -C ₃ H ₇ MgBr (63 g. C ₃ H ₇ Br)	CH ₃ (H ₂ C=CHCH ₂)(<i>n</i> -C ₃ H ₇)COH (yielding 37 g. crude olefin)	136
CH ₃ COCH=CHCH ₃ (35 g.)	CH ₃ MgBr (20 g. Mg)	CH ₃ CH=CH(CH ₃) ₂ COH (8-9 g.); CH ₃ CO- <i>i</i> -C ₄ H ₉ (<i>ca.</i> 30 g.)	111
CH ₃ COCH=CHCH ₃ (40 g.)	CH ₃ MgI (1.5 equiv.)	CH ₃ CH=CH(CH ₃) ₂ COH (80%); CH ₃ CO- <i>i</i> -C ₄ H ₉ (1 g.)	10, 108, 109, 110
CH ₃ COCH=CHCH ₃	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)(CH ₃ CH=CH)COH (41.4%); CH ₃ COCH- <i>s</i> -C ₄ H ₉ (38.6%)	112, 109, 110, 111

*The figure recorded represents the overall yield of alkylated benzene obtained by dehydration of the carbinol and hydrogenation of the resultant olefin.

†Isolated, after AcOH-HBr cyclization, as 2,5,7,8-tetramethyl-2-ethyl-6-chromanol.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₅H₈O (<i>cont.</i>)			
CH ₃ COCH=CHCH ₃ (0.5 mole)	C ₂ H ₅ MgBr (1.0 mole C ₂ H ₅ Br)	CH ₃ COCH ₂ CH(CH ₃)C ₂ H ₅ (52.4 x%)*	622
CH ₃ COCH=CHCH ₃ (0.5 mole)	<i>i</i> -C ₃ H ₇ MgBr (1.0 mole C ₃ H ₇ Br)	CH ₃ COCH ₂ CH(CH ₃)- <i>i</i> -C ₃ H ₇ (65.5 x%)*	622
CH ₃ COCH=CHCH ₃	<i>i</i> -C ₄ H ₉ MgCl	CH ₃ (CH ₃ CH=CH)(<i>i</i> -C ₄ H ₉)COH	109,110
CH ₃ COCH=CHCH ₃	<i>t</i> -C ₄ H ₉ MgCl	CH ₃ (CH ₃ CH=CH)(<i>t</i> -C ₄ H ₉)COH (16.7%); CH ₃ COCH ₂ CH(CH ₃)- <i>t</i> -C ₄ H ₉ (54.0%)	112
CH ₃ COCH=CHCH ₃ (0.5 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.0 mole C ₄ H ₉ Cl)	CH ₃ COCH ₂ CH(CH ₃)- <i>t</i> -C ₄ H ₉ (61.7 x%)*	622
CH ₃ COCH=CHCH ₃	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ (CH ₃ CH=CH)(<i>i</i> -C ₅ H ₁₁)COH	109,110
CH ₃ COCH=CHCH ₃ (40 g.)	C ₆ H ₅ MgBr	CH ₃ (CH ₃ CH=CH)(C ₆ H ₅)COH; CH ₃ COCH ₂ CH(C ₂ H ₅)C ₆ H ₅ (30 g.)	111
CH ₃ COCH=CHCH ₃ (20 g.)	<i>n</i> -C ₄ H ₉ C≡CMgBr (24 g. <i>n</i> -C ₄ H ₉ C≡CH)	CH ₃ (CH ₃ CH=CH)(<i>n</i> -C ₄ H ₉ C≡C)COH (19.5 g.)	83
CH ₃ COCH(CH ₂) ₂ (14 g.)	CH ₃ MgI	(CH ₂) ₂ CH(CH ₃) ₂ COH (9 g.)	113
CH ₃ COCH(CH ₂) ₂	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)[(CH ₂) ₂ CH]COH	114,115, 116
C₅H₈O₃			
CH ₃ COCH ₂ O ₂ CCH ₃	C ₂ H ₅ MgBr (1 equiv.)	CH ₃ (C ₂ H ₅) ₂ COH; CH ₃ (C ₂ H ₅)C(OH)CH ₂ O ₂ CCH ₃ ; recovered keto ester (20%)	82
CH ₃ COCO ₂ C ₂ H ₅ (13 g.)	2-CH ₃ C ₆ H ₄ MgBr (38 g. C ₇ H ₇ Br)	CH ₃ (2-CH ₃ C ₆ H ₄)C(OH)CO ₂ C ₂ H ₅ (50%)	119
CH ₃ COCO ₂ C ₂ H ₅ (29 g.)	4-CH ₃ C ₆ H ₄ MgBr (42 g. C ₇ H ₇ Br)	CH ₃ (4-CH ₃ C ₆ H ₄)C(OH)CO ₂ C ₂ H ₅ (35%)	119
CH ₃ COCO ₂ C ₂ H ₅ (29 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (50 g. C ₉ H ₁₁ Br)	CH ₃ [2,4,6-(CH ₃) ₃ C ₆ H ₂]C(OH)CO ₂ C ₂ H ₅ (20%)	119
CH ₃ COCO ₂ C ₂ H ₅ (14.5 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (50.0 g. C ₉ H ₁₁ Br)	CH ₃ [2,4,6-(CH ₃) ₃ C ₆ H ₂]C(OH)CO ₂ C ₂ H ₅ (50%)	119

*In this study only the relative yields of 1,4-addition products were evaluated. Total yields of products for the reactions studied are said to range from 86 to 100% (*i.e.*, $x = 0.86-1.00$).

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₈O₃ (cont.)			
CH ₃ COCO ₂ C ₂ H ₅ (23.2 g.)	1-C ₁₀ H ₇ MgBr (41.4 g. C ₁₀ H ₇ Br)	CH ₃ (1-C ₁₀ H ₇)C(OH)CO ₂ C ₂ H ₅ (35%)	119
C₅H₉OBr			
CH ₃ COCBr(CH ₃) ₂	CH ₃ MgI	<i>t</i> -C ₄ H ₉ (CH ₃) ₂ COH (62%)	120
C₅H₉OCl			
ClCH ₂ CH ₂ COC ₂ H ₅	C ₂ H ₅ MgBr	ClCH ₂ CH ₂ (C ₂ H ₅) ₂ COH	117
C₅H₉O₂N			
CH ₃ COC(=NOCH ₃)CH ₃	CH ₃ MgI	HO(CH ₃) ₂ CC(=NOCH ₃)CH ₃ (60%)	90
C₅H₁₀O			
CH ₃ CO- <i>n</i> -C ₃ H ₇	(≡CMgBr) ₂	[≡C(CH ₃)(<i>n</i> -C ₃ H ₇)OH] ₂ (70-75%)	118,21,22
CH ₃ CO- <i>n</i> -C ₃ H ₇	H ₂ C=CHCH ₂ Br + Mg	CH ₃ (H ₂ C=CHCH ₂)(<i>n</i> -C ₃ H ₇)COH (88%, crude)	28
CH ₃ CO- <i>n</i> -C ₃ H ₇	<i>i</i> -C ₃ H ₇ MgCl	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>i</i> -C ₃ H ₇)COH (22%); ketol (27%)	96
CH ₃ CO- <i>n</i> -C ₃ H ₇	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>i</i> -C ₃ H ₇)COH (32%)	31,121
CH ₃ CO- <i>n</i> -C ₃ H ₇	H ₂ C=C(CH ₃)CH ₂ MgCl	CH ₃ (<i>n</i> -C ₃ H ₇)[H ₂ C=C(CH ₃)CH ₂]COH; [H ₂ C=C(CH ₃)CH ₂ —] ₂	44
CH ₃ CO- <i>n</i> -C ₃ H ₇	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>n</i> -C ₄ H ₉)COH (68%)	99
CH ₃ CO- <i>n</i> -C ₃ H ₇	<i>t</i> -C ₄ H ₉ MgCl	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>t</i> -C ₄ H ₉)COH	122
CH ₃ CO- <i>n</i> -C ₃ H ₇	<i>n</i> -C ₄ H ₉ C≡CMgBr	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>n</i> -C ₄ H ₉ C≡C)COH (91%)	103
CH ₃ CO- <i>n</i> -C ₃ H ₇ (120 g.)	C ₆ H ₅ C≡CMgBr (143 g. C ₆ H ₅ C≡CH)	CH ₃ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅ C≡C)COH (140 g.)	123
CH ₃ CO- <i>n</i> -C ₃ H ₇ (0.17 mole)	RC≡CMgBr* (0.17 mole)	CH ₃ (<i>n</i> -C ₃ H ₇)(RC≡C)COH* (17.0 g., 48%)	97

*R = 1-Cyclohexenyl.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₁₀O (<i>cont.</i>)			
CH ₃ CO- <i>n</i> -C ₃ H ₇	α -Camphoryl-MgBr*	CH ₃ (<i>n</i> -C ₃ H ₇)(α -C ₁₀ H ₁₅ O)COH (75-79%)	75
CH ₃ CO- <i>n</i> -C ₃ H ₇	2,4,5-(CH ₃) ₃ -3,6- (CH ₃ O) ₂ C ₆ (CH ₂) ₂ MgCl	CH ₃ (<i>n</i> -C ₃ H ₇)[2,4,5-(CH ₃) ₃ -3,6- (CH ₃ O) ₂ C ₆ (CH ₂) ₂]COH†	80
CH ₃ CO- <i>i</i> -C ₃ H ₇	CH ₃ MgCl	Addition, 100%; enolization 0%.†	124
CH ₃ CO- <i>i</i> -C ₃ H ₇	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)(<i>i</i> -C ₃ H ₇)COH (59%)	121
CH ₃ CO- <i>i</i> -C ₃ H ₇ (15 g.)	<i>n</i> -C ₃ H ₇ MgBr (21 g. C ₃ H ₇ Br)	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>i</i> -C ₃ H ₇)COH (10 g.)	126, 37, 121
CH ₃ CO- <i>i</i> -C ₃ H ₇	<i>i</i> -C ₃ H ₇ MgCl	HO(CH ₃)(<i>i</i> -C ₃ H ₇)CCH ₂ CO- <i>i</i> -C ₃ H ₇ (70%)	127
CH ₃ CO- <i>i</i> -C ₃ H ₇	<i>i</i> -C ₃ H ₇ MgCl	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>i</i> -C ₃ H ₇)COH (trace); ketol (70%)	96
CH ₃ CO- <i>i</i> -C ₃ H ₇ (0.3 mole)	<i>i</i> -C ₃ H ₇ MgBr (0.5 mole)	HO(CH ₃)(<i>i</i> -C ₃ H ₇)CCH ₂ CO- <i>i</i> -C ₃ H ₇ (18 g., 70%)	127
CH ₃ CO- <i>i</i> -C ₃ H ₇	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ (<i>i</i> -C ₃ H ₇)(<i>n</i> -C ₄ H ₉)COH (61%)	121, 128
CH ₃ CO- <i>i</i> -C ₃ H ₇	<i>s</i> -C ₄ H ₉ MgBr	HO(CH ₃)(<i>i</i> -C ₃ H ₇)CCH ₂ CO- <i>i</i> -C ₃ H ₇ (37%)	127
CH ₃ CO- <i>i</i> -C ₃ H ₇	<i>t</i> -C ₄ H ₉ MgCl	HO(CH ₃)(<i>i</i> -C ₃ H ₇)CCH ₂ CO- <i>i</i> -C ₃ H ₇ (50%)	127
CH ₃ CO- <i>i</i> -C ₃ H ₇	<i>n</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>i</i> -C ₃ H ₇)(<i>n</i> -C ₅ H ₁₁)COH (60%)	121
CH ₃ CO- <i>i</i> -C ₃ H ₇	C ₆ H ₅ CH ₂ MgCl	CH ₃ (<i>i</i> -C ₃ H ₇)(C ₆ H ₅ CH ₂)COH	68
(C ₂ H ₅) ₂ CO	(\equiv CMgBr) ₂ (excess)	[\equiv CC(C ₂ H ₅) ₂ OH] ₂ (<i>ca.</i> quant.)	22
(C ₂ H ₅) ₂ CO	(\equiv CMgI) ₂	[\equiv CC(C ₂ H ₅) ₂ OH] ₂	125
(C ₂ H ₅) ₂ CO (40 g.)	C ₂ H ₅ MgBr (12 g. Mg.)	(C ₂ H ₅) ₃ COH (91%)	37, 33
(C ₂ H ₅) ₂ CO	C ₂ H ₅ Br + Mg	(C ₂ H ₅) ₃ COH (60%)	104
(C ₂ H ₅) ₂ CO (43 g.)	<i>n</i> -C ₃ H ₇ MgI (90 g. C ₃ H ₇ I)	<i>n</i> -C ₃ H ₇ (C ₂ H ₅) ₂ COH (50 g.)	129
(C ₂ H ₅) ₂ CO	<i>i</i> -C ₃ H ₇ MgCl	Carbinol (<i>none</i>); ketol (52-55%)	96
(C ₂ H ₅) ₂ CO	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ (C ₂ H ₅) ₂ COH (67%)	128
(C ₂ H ₅) ₂ CO	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ (C ₂ H ₅) ₂ COH; C ₆ H ₅ CH ₂ OH; (C ₆ H ₅ CH ₂) ₂	101
(C ₂ H ₅) ₂ CO	1-Indenyl-MgBr	1-Indenyldiethylmethanol	69

*It seems possible (even probable) that this "Grignard reagent" is in fact an enolate.

†Isolated, after AcOH-HBr cyclization, as 2,5,7,8-tetramethyl-2-*n*-propyl-6-chromanol.

‡"Grignard machine" study.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₁₀O₂			
CH ₃ COC(CH ₃) ₂ OH	CH ₃ MgI	[—C(CH ₃) ₂ OH] ₂	130
CH ₃ COC(CH ₃) ₂ OH	H ₂ C=CHCH ₂ MgBr	HO(H ₂ C=CCH ₂)(CH ₃)CC(CH ₃) ₂ OH (70%, crude)	25
C ₂ H ₅ COCH(OH)CH ₃	C ₂ H ₅ MgBr	HO(C ₂ H ₅) ₂ CCH(OH)CH ₃	131
C₆H₄O₃S			
2-Thienylglyoxylic acid	CH ₃ MgI	HO(CH ₃)(2-C ₄ H ₃ S)CCO ₂ H (82%)	132
2-Thienylglyoxylic acid (31.2 g.)	2-Thienyl-MgBr (98.0 g. C ₄ H ₃ SBr)	HO(2-C ₄ H ₃ S) ₂ CCO ₂ H (50.5 g., crude)	132
2-Thienylglyoxylic acid	C ₆ H ₅ MgBr	HO(C ₆ H ₅)(2-C ₄ H ₃ S)CCO ₂ H	132
2-Thienylglyoxylic acid	(CH ₂) ₅ CHMgBr	HO[(CH ₂) ₅ CH](2-C ₄ H ₃ S)CCO ₂ H	132
2-Thienylglyoxylic acid	C ₆ H ₅ CH ₂ MgBr	HO(C ₆ H ₅ CH ₂)(2-C ₄ H ₃ S)CCO ₂ H	132
2-Thienylglyoxylic acid	1-C ₁₀ H ₇ MgBr	HO(1-C ₁₀ H ₇)(2-C ₄ H ₃ S)CCO ₂ H	132
2-Thienylglyoxylic acid	4-C ₆ H ₅ C ₆ H ₄ MgBr	HO(4-C ₆ H ₅ C ₆ H ₄)(2-C ₄ H ₃ S)CCO ₂ H	132
C₆H₁₀O			
CH ₃ CO(CH ₂) ₂ CH=CH ₂ (20.0 g.)	CH ₃ MgI (30.3 g. CH ₃ I)	HO(CH ₃) ₂ C(CH ₂) ₂ CH=CH ₂ (20.0 g.)	241
CH ₃ COCH=CHC ₂ H ₅ (0.5 mole)	C ₂ H ₅ MgBr (1.0 mole C ₂ H ₅ Br)	CH ₃ COCH ₂ CH(C ₂ H ₅) ₂ (43.1 x%)*	622
CH ₃ COCH=CHC ₂ H ₅ (0.5 mole)	<i>i</i> -C ₃ H ₇ MgBr (1.0 mole C ₃ H ₇ Br)	CH ₃ COCH ₂ CH(C ₂ H ₅)- <i>i</i> -C ₃ H ₇ (56.5 x%)*	622
CH ₃ COCH=CHC ₂ H ₅ (0.5 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.0 mole C ₄ H ₉ Cl)	CH ₃ COCH ₂ CH(C ₂ H ₅)- <i>t</i> -C ₄ H ₉ (48.0 x%)*	622
Mesityl oxide [CH ₃ COCH=C(CH ₃) ₂ (ca. 80%) + CH ₃ COCH ₂ C(CH ₃)=CH ₂ (ca. 20%)] [†]	CH ₃ MgBr	(CH ₃) ₂ C=CHC(CH ₃) ₂ OH [†] (75-80%); H ₂ C=C(CH ₃)CH ₂ C(CH ₃) ₂ OH [†] (20-25%)	137,604

*In this study only the relative yields of 1,4-addition products were evaluated. Total yields of products for the reactions studied are said to range from 86 to 100% (*i.e.*, $x = 0.86-1.00$).

[†]These assignments of the constitutions of mesityl oxide and the carbinols are made by Dupont and Menut (137) on the basis of a study of their Raman spectra. The total yield of addition products on the basis of reacting ketone is not stated.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₀O (cont.)			
CH ₃ COCH=C(CH ₃) ₂	CH ₃ MgI	H ₂ C=C(CH ₃)CH=C(CH ₃) ₂	61
CH ₃ COCH=C(CH ₃) ₂	CH ₃ MgI	(CH ₃) ₂ C=CH(CH ₃) ₂ COH (30%); H ₂ C=C(CH ₃)CH=C(CH ₃) ₂ (57%)	613
CH ₃ COCH=C(CH ₃) ₂ (50.0 g.)	CH ₃ MgI (72.4 g. CH ₃ I)	(CH ₃) ₂ C=CH(CH ₃) ₂ COH (17.0 g.)	138,139
CH ₃ COCH=C(CH ₃) ₂	(≡CMgI) ₂	[≡CC(OH)(CH ₃)CH=C(CH ₃) ₂] ₂	125
CH ₃ COCH=C(CH ₃) ₂ (200 g.)	C ₂ H ₅ MgBr (70 g. Mg)	CH ₃ (C ₂ H ₅)[(CH ₃) ₂ CH=CH]COH	111,140, 604
CH ₃ COCH=C(CH ₃) ₂	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)[(CH ₃) ₂ CH=CH]COH (>50.9%); CH ₃ COCH ₂ C(CH ₃) ₂ C ₂ H ₅ (ca. 6.5%)*	141
CH ₃ COCH=C(CH ₃) ₂	C ₂ H ₅ MgBr	H ₂ C=C(C ₂ H ₅)CH=C(CH ₃) ₂ ; higher-boiling isomer.†	141
CH ₃ COCH=C(CH ₃) ₂	C ₂ H ₅ MgI	CH ₃ (C ₂ H ₅)[(CH ₃) ₂ C=CH]COH	232
CH ₃ COCH=C(CH ₃) ₂	H ₂ C=CHCH ₂ MgBr	CH ₃ (H ₂ C=CHCH ₂)[(CH ₃) ₂ C=CH]COH (91%, crude)	25,142, 143
CH ₃ COCH=C(CH ₃) ₂	H ₂ C=CHCH ₂ Br + Mg	CH ₃ (H ₂ C=CHCH ₂)[(CH ₃) ₂ C=CH]COH (75%)	599
CH ₃ COCH=C(CH ₃) ₂	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)[(CH ₃) ₂ C=CH]COH	232,604
CH ₃ COCH=C(CH ₃) ₂	<i>i</i> -C ₃ H ₇ MgBr	C ₉ H ₁₇ OH	144
CH ₃ COCH=C(CH ₃) ₂	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ (<i>i</i> -C ₃ H ₇)[(CH ₃) ₂ C=CH]COH	604
CH ₃ COCH=C(CH ₃) ₂	H ₂ C=CHC≡CMgBr	H ₂ C=CHC≡CC(=CH ₂)CH=C(CH ₃) ₂ (40%)	40
CH ₃ COCH=C(CH ₃) ₂	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ (<i>n</i> -C ₄ H ₉)[(CH ₃) ₂ C=CH]COH	604
CH ₃ COCH=C(CH ₃) ₂	<i>n</i> -C ₄ H ₉ MgI	CH ₃ (<i>n</i> -C ₄ H ₉)[(CH ₃) ₂ C=CH]COH	232
CH ₃ COCH=C(CH ₃) ₂	<i>i</i> -C ₄ H ₉ MgBr	CH ₃ (<i>i</i> -C ₄ H ₉)[(CH ₃) ₂ C=CH]COH	604

*Simultaneous addition of Grignard reagent and Et₂O-ketone solutions to Et₂O at -10°. The overall yield of diene upon dehydration of the carbinole was 50.9%.

†Simultaneous addition of Grignard reagent and Et₂O-ketone solutions to Et₂O at 15°. The total yield of crude dienes was 17.3%.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₀O (cont.)			
CH ₃ COCH=C(CH ₃) ₂	<i>t</i> -C ₄ H ₉ MgCl	CH ₃ [(CH ₃) ₂ C=CH] (<i>t</i> -C ₄ H ₉)COH (46%); no 1,4 add'n.	112,144
CH ₃ COCH=C(CH ₃) ₂	<i>n</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>n</i> -C ₅ H ₁₁)[(CH ₃) ₂ C=CH]COH	604
CH ₃ COCH=C(CH ₃) ₂	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>i</i> -C ₅ H ₁₁)[(CH ₃) ₂ C=CH]COH	604
CH ₃ COCH=C(CH ₃) ₂	<i>i</i> -C ₅ H ₁₁ MgBr	Dienes, only.	145
CH ₃ COCH=C(CH ₃) ₂ (318.5 g., 3.25 moles)	<i>t</i> -C ₅ H ₁₁ MgCl (3.5 moles)	CH ₃ COCH ₂ C(CH ₃) ₂ - <i>t</i> -C ₅ H ₁₁ (16.2%); dienes (8.3%); recovered ketone (8.0%); condensate	305
CH ₃ COCH=C(CH ₃) ₂ (25 g.)	C ₆ H ₅ MgBr (38 g. C ₆ H ₅ Br)	CH ₃ (C ₆ H ₅)C=C=C(CH ₃) ₂ (18 g.)	146,147
CH ₃ COCH=C(CH ₃) ₂ (12.0 g.)	<i>n</i> -C ₄ H ₉ C≡CMgBr (11.3 g. <i>n</i> -C ₄ H ₉ C≡CH)	CH ₃ [(CH ₃) ₂ C=CH] (<i>n</i> -C ₄ H ₉ C≡C)COH (14.2 g.)	83
CH ₃ COCH=C(CH ₃) ₂	C ₆ H ₅ CH ₂ MgCl	CH ₃ [(CH ₃) ₂ C=CH] (C ₆ H ₅ CH ₂)COH	148
CH ₃ COCH=C(CH ₃) ₂	C ₆ H ₅ CH(CO ₂ Na)MgCl*	CH ₃ [(CH ₃) ₂ C=CH] [C ₆ H ₅ (HO ₂ C)CH]COH ("good yield")	149
CH ₃ COCH=C(CH ₃) ₂ (24.5 g.)	9-Fluorenyl-MgBr	Fluorene (27%); 4-(9-fluorenylidene)-2- methyl-2-pentene (30%)	626
CH ₃ COC(CH ₃)=CHCH ₃	CH ₃ MgI	CH ₃ CH=C(CH ₃)C(CH ₃) ₂ OH (70%)	150
CH ₃ COC(CH ₃)=CHCH ₃	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ [CH ₃ CH=C(CH ₃)] (<i>n</i> -C ₄ H ₉)COH + CH ₃ COCH(CH ₃)CH(CH ₃)- <i>n</i> -C ₄ H ₉ (in ratio of ca. 77 : 23)	150
C ₂ H ₅ COCH=CHCH ₃ (0.5 mole)	C ₂ H ₅ MgBr (1.0 mole C ₂ H ₅ Br)	C ₂ H ₅ COCH ₂ CH(CH ₃)C ₂ H ₅ (67.7 x%) [†]	622
C ₂ H ₅ COCH=CHCH ₃ (0.5 mole)	<i>i</i> -C ₃ H ₇ MgBr (1.0 mole C ₃ H ₇ Br)	C ₂ H ₅ COCH ₂ CH(CH ₃)- <i>i</i> -C ₃ H ₇ (80.2 x%) [†]	622

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

[†]In this study only the relative yields of 1,4-addition products were evaluated. Total yields of products for the reactions studied are said to range from 86 to 100% (*i.e.*, $x = 0.86-1.00$).

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₆H₁₀O (<i>cont.</i>)			
C ₂ H ₅ COCH=CHCH ₃ (0.5 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.0 mole C ₄ H ₉ Cl)	C ₂ H ₅ COCH ₂ CH(CH ₃)- <i>t</i> -C ₄ H ₉ (66.3 x%)*	622
C ₂ H ₅ COCH(CH ₂) ₂	CH ₃ MgBr	CH ₃ (C ₂ H ₅)[(CH ₂) ₂ CH]COH	114, 115
C ₂ H ₅ COCH(CH ₂) ₂	C ₂ H ₅ MgBr	(CH ₂) ₂ CH(C ₂ H ₅) ₂ COH	115
C ₂ H ₅ COCH(CH ₂) ₂	<i>n</i> -C ₃ H ₇ MgBr	C ₂ H ₅ [(CH ₂) ₂ CH](<i>n</i> -C ₃ H ₇)COH	115
C ₂ H ₅ COCH(CH ₂) ₂	<i>n</i> -C ₄ H ₉ MgBr	C ₂ H ₅ [(CH ₂) ₂ CH](<i>n</i> -C ₄ H ₉)COH	115
C ₂ H ₅ COCH(CH ₂) ₂	<i>n</i> -C ₅ H ₁₁ MgBr	C ₂ H ₅ [(CH ₂) ₂ CH](<i>i</i> -C ₅ H ₁₁)COH	115
C₆H₁₀O₂			
(CH ₃ COCH ₂ —) ₂	(≡CMgBr) ₂	HO(CH ₃)(HC≡C)CH ₂ CH ₂ COCH ₃	82
C₆H₁₀O₃			
CH ₃ COCH ₂ CO ₂ C ₂ H ₅ (65 g.)	CH ₃ MgI (1 equiv.)	Forms enolate, Mg(C ₆ H ₉ O ₃) ₂ ; 57 g. ketone recovered; CH ₄	151, 152
C₆H₁₁OCl			
CH ₃ COCCl(CH ₃) ₂	CH ₃ MgBr	<i>t</i> -C ₄ H ₉ OH; (CH ₃)C=CH ₂	161
CH ₃ COCCl(CH ₃) ₂	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅) ₂ COH; (C ₂ H ₅) ₂ C=CH ₂ ; (CH ₃) ₂ C=CH ₂	161
CH ₃ COCCl(CH ₃) ₂	C ₆ H ₅ MgBr	CH ₃ (C ₆ H ₅) ₂ COH; (C ₆ H ₅) ₂ C=CH ₂ ; (CH ₃) ₂ C=CH ₂	161
CH ₃ COCCl(CH ₃) ₂	(CH ₂) ₅ CHMgBr	CH ₃ [(CH ₂) ₅ CH] ₂ COH; [(CH ₂) ₅ CH] ₂ C=CH ₂ ; (CH ₃) ₂ C=CH ₂	161
C₆H₁₁ON			
CH ₃ COCH=CHN(CH ₃) ₂	C ₆ H ₅ MgBr	CH ₃ COCH=CHC ₆ H ₅	153

*In this study only the relative yields of 1,4-addition products were evaluated. Total yields of products for the reactions studied are said to range from 86 to 100% (*i.e.*, $x = 0.86-1.00$).

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₆H₁₁O₂Cl			
CH ₃ COCHClC(CH ₃) ₂ OH	CH ₃ MgI (2 equiv.)	[HO(CH ₃) ₂ C] ₂ CHOH (40-60%)	154,155
C₆H₁₂O			
CH ₃ CO- <i>n</i> -C ₄ H ₉	(≡CMgI) ₂	[≡CC(CH ₃)(<i>n</i> -C ₄ H ₉)OH] ₂	125
CH ₃ CO- <i>n</i> -C ₄ H ₉	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₄ H ₉)COH (<i>ca.</i> quant.)	156
CH ₃ CO- <i>n</i> -C ₄ H ₉	C ₂ H ₅ MgI	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₄ H ₉)COH	157
CH ₃ CO- <i>n</i> -C ₄ H ₉	<i>n</i> -C ₃ H ₇ MgI	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>n</i> -C ₄ H ₉)COH	158
CH ₃ CO- <i>n</i> -C ₄ H ₉ (2.0 moles)	<i>n</i> -C ₄ H ₉ MgBr (4.5 moles)	CH ₃ (<i>n</i> -C ₄ H ₉) ₂ COH; olefin (0.15 mole); CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (11.8 g., 9%); recovered ketone (19.3 g.)	159
CH ₃ CO- <i>n</i> -C ₄ H ₉ (165 g., 1.65 mole)	(CH ₂) ₅ C(OH)C≡CH (186 g., 1.5 mole) + C ₂ H ₅ MgBr (380 g., 3.48 moles C ₂ H ₅ Br)	1-(3-Hydroxy-3-methyl-1-heptynyl)- cyclohexanol (207-214 g., 59-61%)	160
CH ₃ CO- <i>i</i> -C ₄ H ₉	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)(<i>i</i> -C ₄ H ₉)COH (77%)	162
CH ₃ CO- <i>i</i> -C ₄ H ₉	C ₂ H ₅ MgI	CH ₃ (C ₂ H ₅)(<i>i</i> -C ₄ H ₉)COH (40-60%); * C ₈ H ₁₆ ; C ₂ H ₆	142
CH ₃ CO- <i>i</i> -C ₄ H ₉	H ₂ C=CHCH ₂ MgBr	CH ₃ (H ₂ C=CHCH ₂)(<i>i</i> -C ₄ H ₉)COH (83%, crude)	25,142, 143
CH ₃ CO- <i>i</i> -C ₄ H ₉	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>i</i> -C ₄ H ₉)COH (40-60%); * C ₉ H ₁₈ ; C ₃ H ₈	142
CH ₃ CO- <i>i</i> -C ₄ H ₉ (70 g.)	<i>n</i> -C ₃ H ₇ MgI (171 g. CH ₃ I)	H ₂ C=C(<i>n</i> -C ₃ H ₇)(<i>i</i> -C ₃ H ₇)(?) [†] (20 g.)	164
CH ₃ CO- <i>i</i> -C ₄ H ₉	<i>i</i> -C ₃ H ₇ MgCl	Carbinol (<i>none</i>); ketol (55%)	96
CH ₃ CO- <i>i</i> -C ₄ H ₉	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ (<i>i</i> -C ₃ H ₇)(<i>i</i> -C ₄ H ₉)COH	54

*Carbinol yields of 40-60% are reported for a series of reactions studied.

[†]Although this product is once mentioned (evidently through a slip of the pen) as "2-methene-4-methylheptane," there is no doubt that the compound reported is that represented by the formula above. It would appear much more probable, however, that the carbinol dehydration product is CH₃(*n*-C₃H₇)CHCH=C(CH₃)₂ or a mixture thereof with CH₃(*i*-C₃H₇)C=CH-*n*-C₃H₇.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₆H₁₂O (cont.)			
CH ₃ CO- <i>i</i> -C ₄ H ₉	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ (<i>n</i> -C ₄ H ₉)(<i>i</i> -C ₄ H ₉)COH	54
CH ₃ CO- <i>i</i> -C ₄ H ₉	<i>i</i> -C ₄ H ₉ MgBr	CH ₃ (<i>i</i> -C ₄ H ₉) ₂ COH (40-60%)*	142
CH ₃ CO- <i>i</i> -C ₄ H ₉	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>i</i> -C ₄ H ₉)(<i>i</i> -C ₅ H ₁₁)COH	54
CH ₃ CO- <i>i</i> -C ₄ H ₉	C ₆ H ₅ MgBr	CH ₃ (<i>i</i> -C ₄ H ₉)(C ₆ H ₅)COH (40-60%);* CH ₃ (C ₆ H ₅)C=CH- <i>i</i> -C ₃ H ₇ ; C ₆ H ₆	142
CH ₃ CO- <i>i</i> -C ₄ H ₉	2,4,5-(CH ₃) ₃ -3,6- (CH ₃ O) ₂ C ₆ (CH ₂) ₂ MgCl	CH ₃ (<i>i</i> -C ₄ H ₉)[2,4,5-(CH ₃) ₃ -3,6- (CH ₃ O) ₂ C ₆ (CH ₂) ₂]COH [†]	80
CH ₃ CO- <i>s</i> -C ₄ H ₉	CH ₃ MgCl	Addition (?%); enolization (32%) [†]	124
CH ₃ CO- <i>t</i> -C ₄ H ₉	CH ₃ MgCl	Addition (86%); enolization (5%) [†]	124
CH ₃ CO- <i>t</i> -C ₄ H ₉	CH ₃ MgBr	Addition (86%); enolization (5%) [†]	168
CH ₃ CO- <i>t</i> -C ₄ H ₉	CH ₃ MgBr	Carbinol (?%); ketol (6%)	96
CH ₃ CO- <i>t</i> -C ₄ H ₉ (10 g.)	CH ₃ MgBr (3 g. Mg)	<i>t</i> -C ₄ H ₉ (CH ₃) ₂ COH (12 g.)	166,18
CH ₃ CO- <i>t</i> -C ₄ H ₉	CH ₃ MgI	<i>t</i> -C ₄ H ₉ (CH ₃) ₂ COH (90%); HO(CH ₃)(<i>t</i> -C ₄ H ₉)CCH ₂ CO- <i>t</i> -C ₄ H ₉ (6%)	167,31
CH ₃ CO- <i>t</i> -C ₄ H ₉	(≡CMgBr) ₂	[≡CC(CH ₃)(<i>t</i> -C ₄ H ₉)OH] ₂ (80%)	118,19
CH ₃ CO- <i>t</i> -C ₄ H ₉	C ₂ H ₅ MgBr	Carbinol (?%); ketol (7.5%)	96
CH ₃ CO- <i>t</i> -C ₄ H ₉ (50 g.)	C ₂ H ₅ MgBr (82 g. C ₂ H ₅ Br)	CH ₃ (C ₂ H ₅)(<i>t</i> -C ₄ H ₉)COH (34 g.)	169,31,35, 170
CH ₃ CO- <i>t</i> -C ₄ H ₉	C ₂ H ₅ MgBr	CH ₃ (<i>t</i> -C ₄ H ₉)C=CHCO- <i>t</i> -C ₄ H ₉ ; HO(CH ₃)(<i>t</i> -C ₄ H ₉)CCH ₂ CO- <i>t</i> -C ₄ H ₉	165
CH ₃ CO- <i>t</i> -C ₄ H ₉	CH ₃ C≡CMgBr	CH ₃ (CH ₃ C≡C)(<i>t</i> -C ₄ H ₉)COH (50%)	118
CH ₃ CO- <i>t</i> -C ₄ H ₉	<i>n</i> -C ₃ H ₇ MgCl	Carbinol (? %); ketol (19%)	96
CH ₃ CO- <i>t</i> -C ₄ H ₉	<i>n</i> -C ₃ H ₇ MgCl	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>t</i> -C ₄ H ₉)COH (ca. 25%); CH ₃ (<i>t</i> -C ₄ H ₉)CHOH; C ₃ H ₆ ; C ₃ H ₈	171

*Carbinol yields of 40-60% are reported for a series of reactions studied.

[†]Isolated, after AcOH-HBr cyclization, as 2,5,7,8-tetramethyl-2-isobutyl-6-chromanol.

[‡]"Grignard machine" study.

TABLE VI-XVIII (Continued)

Ketonic Comp'd	RMgX	Product(s)	Ref.
C₆H₁₂O (cont.)			
CH ₃ CO- <i>t</i> -C ₄ H ₉	<i>i</i> -C ₃ H ₇ MgCl	Carbinol (? %); ketol (62%)	96
CH ₃ CO- <i>t</i> -C ₄ H ₉	<i>i</i> -C ₃ H ₇ MgCl	HO(CH ₃)(<i>t</i> -C ₄ H ₉)CCH ₂ CO- <i>t</i> -C ₄ H ₉ (43%)	127
CH ₃ CO- <i>t</i> -C ₄ H ₉	<i>s</i> -C ₄ H ₉ MgBr	HO(CH ₃)(<i>t</i> -C ₄ H ₉)CCH ₂ CO- <i>t</i> -C ₄ H ₉ (45%)	127
CH ₃ CO- <i>t</i> -C ₄ H ₉	<i>t</i> -C ₄ H ₉ MgCl	HO(CH ₃)(<i>t</i> -C ₄ H ₉)CCH ₂ CO- <i>t</i> -C ₄ H ₉ (48%)	127
CH ₃ CO- <i>t</i> -C ₄ H ₉	<i>t</i> -C ₄ H ₉ MgCl	CH ₃ (<i>t</i> -C ₄ H ₉)CHOH; CH ₃ (<i>t</i> -C ₄ H ₉)C=CHCO- <i>t</i> -C ₄ H ₉ ; HO(CH ₃)(<i>t</i> -C ₄ H ₉)CCH ₂ CO- <i>t</i> -C ₄ H ₉ ; (no add'n product)	165
CH ₃ CO- <i>t</i> -C ₄ H ₉	(+)-CH ₃ (C ₂ H ₅)CHCH ₂ MgCl*	CH ₃ (<i>t</i> -C ₄ H ₉)CHOH, [α] _D ²⁰ + 0.42 to [α] _D ²⁰ + 0.70 (9.0-35.6%); CH ₃ (<i>t</i> -C ₄ H ₉)[CH ₃ (C ₂ H ₅)CHCH ₂]COH + ketol (aggregating 8.1-37.9%); H ₂ C=C(CH ₃)C ₂ H ₅ (6.2-31.2%); recovered ketone (11.1-39.5%) [†]	612
CH ₃ CO- <i>t</i> -C ₄ H ₉	C ₆ H ₅ MgBr	CH ₃ (<i>t</i> -C ₄ H ₉)(C ₆ H ₅)COH (60%)	172,232
CH ₃ CO- <i>t</i> -C ₄ H ₉	C ₆ H ₅ MgBr	CH ₃ (<i>t</i> -C ₄ H ₉)C=CHCO- <i>t</i> -C ₄ H ₉ ; HO(CH ₃)(<i>t</i> -C ₄ H ₉)CCH ₂ CO- <i>t</i> -C ₄ H ₉	165
CH ₃ CO- <i>t</i> -C ₄ H ₉ (55.0 g., 0.55 mole)	(+)-CH ₃ (C ₂ H ₅)CH(CH ₂) ₂ MgCl [‡] (87.2 g., 0.72 mole C ₆ H ₁₃ Cl)	(+)-CH ₃ (<i>t</i> -C ₄ H ₉)CHOH (0.001 mole, 0.2%); CH ₃ (C ₂ H ₅)CHCH=CH ₂ (0.0009 mole); CH ₃ (C ₂ H ₅) ₂ CH; recovered ketone (53%); add'n and/or cond'n products (ca. 20%)	612
C ₂ H ₅ CO- <i>n</i> -C ₃ H ₇	C ₆ H ₅ CH ₂ Cl + Mg	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅ CH ₂)COH (60%); dehydr'n product	104
C ₂ H ₅ CO- <i>i</i> -C ₃ H ₇	CH ₃ MgCl	Addition (100%); enolization (0%) [§]	124
C ₂ H ₅ CO- <i>i</i> -C ₃ H ₇	C ₂ H ₅ MgBr	<i>i</i> -C ₃ H ₇ (C ₂ H ₅) ₂ COH	37

*Prepared from (+)-CH₃(C₂H₅)CHCH₂Cl of 94-96% optical purity.

†The reaction was conducted under a variety of conditions; total yields of recovered products ranged from 66.9 to 83.5%.

‡Prepared from (+)-CH₃(C₂H₅)CH(CH₂)₂Cl of 74% optical purity.

§"Grignard machine" study.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₂O (<i>cont.</i>)			
C ₂ H ₅ CO- <i>i</i> -C ₃ H ₇ (25 g.)	<i>n</i> -C ₃ H ₇ MgBr (10 g. Mg)	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(<i>i</i> -C ₃ H ₇)COH (<i>ca.</i> quant.)	37
C ₂ H ₅ CO- <i>i</i> -C ₃ H ₇	<i>i</i> -C ₃ H ₇ MgCl	Carbinol (none); ketol (60%)	96
C ₂ H ₅ CO- <i>i</i> -C ₃ H ₇ (25 g.)	<i>i</i> -C ₃ H ₇ MgBr (10 g. Mg)	C ₂ H ₅ (<i>i</i> -C ₃ H ₇) ₂ COH (50%); C ₂ H ₅ (<i>i</i> -C ₃ H ₇)CHOH (30%)	37
C₆H₁₂O₂			
CH ₃ COCH ₂ C(CH ₃) ₂ OH	CH ₃ MgBr	[HO(CH ₃) ₂ C] ₂ CH ₂	174, 107
CH ₃ COCH ₂ C(CH ₃) ₂ OH	CH ₃ MgI (2 equiv.)	[HO(CH ₃) ₂ C] ₂ CH ₂	177, 178
CH ₃ COCH ₂ C(CH ₃) ₂ OH (350 g.)	C ₂ H ₅ MgBr (2.25 equiv.)	HO(CH ₃) ₂ CCH ₂ C(CH ₃)(C ₂ H ₅)OH (160 g.)	175, 176
CH ₃ COCH ₂ C(CH ₃) ₂ OH	<i>n</i> -C ₃ H ₇ MgBr	HO(CH ₃) ₂ CCH ₂ C(CH ₃)(<i>n</i> -C ₃ H ₇)OH	176
CH ₃ COCH ₂ C(CH ₃) ₂ OH	<i>i</i> -C ₃ H ₇ MgBr	HO(CH ₃) ₂ CCH ₂ C(CH ₃)(<i>i</i> -C ₃ H ₇)OH	176
CH ₃ COCH ₂ C(CH ₃) ₂ OH	<i>n</i> -C ₄ H ₉ MgBr	HO(CH ₃) ₂ CCH ₂ C(CH ₃)(<i>n</i> -C ₄ H ₉)OH	176
CH ₃ COCH ₂ C(CH ₃) ₂ OH	<i>i</i> -C ₄ H ₉ MgBr	HO(CH ₃) ₂ CCH ₂ C(CH ₃)(<i>i</i> -C ₄ H ₉)OH	176
CH ₃ COCH ₂ C(CH ₃) ₂ OH	<i>n</i> -C ₅ H ₁₁ MgBr	HO(CH ₃) ₂ CCH ₂ C(CH ₃)(<i>n</i> -C ₅ H ₁₁)OH	176
CH ₃ COCH ₂ C(CH ₃) ₂ OH	<i>i</i> -C ₅ H ₁₁ MgBr	HO(CH ₃) ₂ CCH ₂ C(CH ₃)(<i>i</i> -C ₅ H ₁₁)OH	176
C ₂ H ₅ COCH(OH)C ₂ H ₅ (30 g.)	C ₆ H ₅ MgBr (130 g. C ₆ H ₅ Br)	HO(C ₂ H ₅)(C ₆ H ₅)CCH(OH)C ₂ H ₅	179
C ₂ H ₅ COCH(OH)C ₂ H ₅ (11.6 g.)	(CH ₂) ₅ CHMgBr (41 g., C ₆ H ₁₁ Br)	HO(C ₂ H ₅)[(CH ₂) ₅ CH]CCH(OH)C ₂ H ₅ (2.2 g.)	173
C ₂ H ₅ COCH(OH)C ₂ H ₅ (39 g.)	4-CH ₃ OC ₆ H ₄ MgBr (180 g. C ₇ H ₇ OBr)	HO(C ₂ H ₅)(4-CH ₃ OC ₆ H ₄)CCH(OH)C ₂ H ₅ (20-25 g.)	173
C₇H₇ON			
3-Acetopyridine	C ₆ H ₅ (1-C ₁₀ H ₇)C≡CHMgBr	C ₆ H ₅ (1-C ₁₀ H ₇)C≡CH(C ₅ H ₄ N)(CH ₃)COH (30%)	180
C₇H₆OS			
2-Propionylthiophene	C ₂ H ₅ MgI	<i>α</i> -C ₄ H ₃ S(C ₂ H ₅) ₂ COH	181

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₀O			
CH ₃ COCH=CHCH=CHCH ₃ (55 g.)	RC≡CMgBr* (62 g. RC≡CH*)	CH ₃ (CH ₃ CH=CHCH=CH)(RC≡C)COH* (60 g.)	182,630
C₇H₁₀O₃			
H ₅ C ₂ O ₂ C(C ₂ H ₅)C=CO (11.0 g., 0.077 mole)	C ₆ H ₅ MgBr (0.2 mole)	C ₂ H ₅ (C ₆ H ₅ CO)C=C(C ₆ H ₅) ₂ (2.5 g.); C ₂ H ₅ (C ₆ H ₅ CO)CHCO ₂ C ₂ H ₅ (5.0 ml) [†]	606
H ₅ C ₂ O ₂ C(C ₂ H ₅)C=CO (8.5 g., 0.06 mole)	C ₆ H ₅ MgBr (0.2 mole)	C ₂ H ₅ (C ₆ H ₅ CO)CHCO ₂ C ₂ H ₅ (6.0 g.); <i>n</i> -C ₃ H ₇ COC ₆ H ₅ (<2.0 g.) [‡]	606
C₇H₁₀O₅			
(H ₅ C ₂ O ₂ C) ₂ CO (29.0 g.)	2-CH ₃ C ₆ H ₄ MgBr (28.5 g. C ₇ H ₇ Br)	2-CH ₃ C ₆ H ₄ (H ₅ C ₂ O ₂ C) ₂ COH (30%)	119
(H ₅ C ₂ O ₂ C) ₂ CO (43.5 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (50.0 g. C ₉ H ₁₁ Br)	2,4,6-(CH ₃) ₃ C ₆ H ₄ (H ₅ C ₂ O ₂ C) ₂ COH (25%)	119
(H ₅ C ₂ O ₂ C) ₂ CO (43.0 g.)	1-C ₁₀ H ₇ MgBr (52.0 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ (H ₅ C ₂ O ₂ C) ₂ COH (40%)	119
C₇H₁₂O			
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇	CH ₃ MgI	<i>n</i> -C ₃ H ₇ CH=CH(CH ₃) ₂ COH (75%); ketol ("a little")	183
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇ (10.5 g.)	CH ₃ MgI (17.0 g. CH ₃ I)	<i>n</i> -C ₃ H ₇ CH=CH(CH ₃) ₂ COH (yielding 16.0% diene)	184
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇ (10.5 g.)	CH ₃ MgI (34.0 g. CH ₃ I)	<i>n</i> -C ₃ H ₇ CH=CH(CH ₃) ₂ COH (yielding 29.5% diene)	184
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₃ H ₇ CH=CH)COH (65%)	183

*R = 1-Cyclohexenyl.

[†]Dropwise addition of Et₂O-ketene solution to Grignard reagent solution.[‡]Dropwise addition of Grignard reagent solution to Et₂O-ketene solution; half-hour reflux.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₇H₁₂O (cont.)			
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇ (37.0 g.)	C ₂ H ₅ MgBr (13.6 g. Mg)	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₃ H ₇ CH=CH)COH (<i>ca.</i> 21.6 g.); CH ₃ COCH ₂ CH(C ₂ H ₅)(<i>n</i> -C ₃ H ₇) (<i>ca.</i> 14.4 g.)	185
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇ (56.0 g., 0.5 mole)	C ₂ H ₅ MgBr (24.2 g., 1.0 mole C ₂ H ₅ Br)	CH ₃ COCH ₂ CH(C ₂ H ₅)- <i>i</i> -C ₃ H ₇ (52.0 x%)*	622
<i>trans</i> -CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₃ H ₇ CH=CH)COH (75.8 x%); CH ₃ COCH ₂ CH(C ₂ H ₅)- <i>n</i> -C ₃ H ₇ (24.2 x%)	186
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>n</i> -C ₃ H ₇ CH=CH)COH (55%)	183
<i>trans</i> -CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ (<i>i</i> -C ₃ H ₇)(<i>n</i> -C ₃ H ₇ CH=CH)COH (53.7 x%); CH ₃ COCH ₂ CH(<i>n</i> -C ₃ H ₇)- <i>i</i> -C ₃ H ₇ (46.3 x%)	186
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇ (0.5 mole)	<i>i</i> -C ₃ H ₇ MgBr (1.0 mole C ₃ H ₇ Br)	CH ₃ COCH ₂ CH(<i>n</i> -C ₃ H ₇)- <i>i</i> -C ₃ H ₇ (63.0 x%)*	622
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ (<i>n</i> -C ₄ H ₉)(<i>n</i> -C ₃ H ₇ CH=CH)COH (45%)	183
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇	<i>i</i> -C ₄ H ₉ MgBr	CH ₃ (<i>i</i> -C ₄ H ₉)(<i>n</i> -C ₃ H ₇ CH=CH)COH (38%)	183
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇ (0.5 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.0 mole C ₄ H ₉ Cl)	CH ₃ COCH ₂ CH(<i>n</i> -C ₃ H ₇)- <i>t</i> -C ₄ H ₉ (59.9 x%)*	622
<i>trans</i> -CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇	<i>t</i> -C ₄ H ₉ MgCl	CH ₃ (<i>t</i> -C ₄ H ₉)(<i>n</i> -C ₃ H ₇ CH=CH)COH (65.1 x%); CH ₃ COCH ₂ CH(<i>n</i> -C ₃ H ₇)- <i>t</i> -C ₄ H ₉ (34.9 x%)	186
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>i</i> -C ₅ H ₁₁)(<i>n</i> -C ₃ H ₇ CH=CH)COH (30%)	183
CH ₃ COCH=CH- <i>n</i> -C ₃ H ₇	C ₆ H ₅ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇ CH=CH)(C ₆ H ₅)COH (20%)	183, 184
(CH ₂) ₂ CHCO- <i>n</i> -C ₃ H ₇	CH ₃ MgBr	CH ₃ [(CH ₂) ₂ CH](<i>n</i> -C ₃ H ₇)COH	115
(CH ₂) ₂ CHCO- <i>n</i> -C ₃ H ₇	<i>n</i> -C ₃ H ₇ MgBr	(CH ₂) ₂ CH(<i>n</i> -C ₃ H ₇) ₂ COH	115
(CH ₂) ₂ CHCO- <i>n</i> -C ₃ H ₇	<i>n</i> -C ₄ H ₉ MgBr	(CH ₂) ₂ CH(<i>n</i> -C ₃ H ₇)(<i>n</i> -C ₄ H ₉)COH	115
(CH ₂) ₂ CHCO- <i>n</i> -C ₃ H ₇	<i>n</i> -C ₅ H ₁₁ MgBr	(CH ₂) ₂ CH(<i>n</i> -C ₃ H ₇)(<i>n</i> -C ₅ H ₁₁)COH	115
(CH ₂) ₂ CHCO- <i>n</i> -C ₃ H ₇	<i>n</i> -C ₆ H ₁₃ MgBr	(CH ₂) ₂ CH(<i>n</i> -C ₃ H ₇)(<i>n</i> -C ₆ H ₁₃)COH	115

*In this study only the relative yields of 1,4-addition products were evaluated. Total yields of products for the reactions studied are said to range from 86-100% (*i.e.*, $x = 0.86-1.00$).

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₂O₃			
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅ (130.2 g.)	CH ₃ MgI (142.0 g. CH ₃ I)	γ,γ-Dimethylbutyrolactone (63.7 g., 62%)	580
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr (1 equiv.)	γ-Hydroxy-γ-methylcaproic acid γ-lactone (35%)	151,187
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr (3 equiv.)	HO(CH ₃)(C ₂ H ₅)C(CH ₂) ₂ C(C ₂ H ₅) ₂ OH (63%)	151,187
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅	CH ₃ C≡CMgBr	HO(CH ₃)(CH ₃ C≡C)C(CH ₂) ₂ C(C≡CCH ₃) ₂ OH	608
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅ (212.0 g.)	<i>n</i> -C ₃ H ₇ MgBr (207.0 g. C ₃ H ₇ Br)	γ-Methyl-γ- <i>n</i> -propylbutyrolactone (157.6 g., 73.3%)	607
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅	<i>n</i> -C ₅ H ₁₁ MgCl (213 g. C ₅ H ₁₁ Cl)	γ-Hydroxy-γ-methylpelargonic acid γ-lactone (<i>ca.</i> 98 g.)	189
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr (1 equiv.)	γ-Hydroxy-γ,ζ-dimethylcaprylic acid γ-lactone	151,187
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr (3 equiv.)	HO(CH ₃)(<i>i</i> -C ₅ H ₁₁)C(CH ₂) ₂ C(<i>i</i> -C ₅ H ₁₁) ₂ OH	151,187
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr (1 equiv.)	γ-Hydroxy-γ-phenylvaleric acid γ-lactone (30%)	187
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅ (2 moles)	<i>n</i> -C ₆ H ₁₃ MgCl (2 moles C ₆ H ₁₃ Cl)	γ-Hydroxy-γ-methylcapric acid γ-lactone (103.2 g., 28%); recovered ketone (25.1 g.)	188
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅ (2 moles)	<i>n</i> -C ₆ H ₁₃ MgBr (2 moles C ₆ H ₁₃ Br)	γ-Hydroxy-γ-methylcapric acid γ-lactone (113.0 g., 31%)	188
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅ (26.0 g.)	<i>n</i> -C ₁₀ H ₂₁ MgBr (44.2 g. C ₁₀ H ₂₁ Br)	γ-Methyl-γ- <i>n</i> -decylbutyrolactone (36.4 g., 84.4%)	607
C₇H₁₃ON			
CH ₃ COC(CH ₃)=CHN(CH ₃) ₂	CH ₃ MgI (1.5 equiv.)	CH ₃ COC(CH ₃)=CHCH ₃	153
CH ₃ COC(CH ₃)=CHN(CH ₃) ₂	C ₂ H ₅ MgBr (1.5 equiv.)	CH ₃ COC(CH ₃)=CHC ₂ H ₅	153

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₄O			
CH ₃ CO- <i>n</i> -C ₅ H ₁₁	CH ₃ MgCl	<i>n</i> -C ₅ H ₁₁ (CH ₃) ₂ COH (61%)	191
CH ₃ CO- <i>n</i> -C ₅ H ₁₁	(≡CMgBr) ₂	[≡C(CH ₃)(<i>n</i> -C ₅ H ₁₁)OH] ₂ (72-76%)	631
CH ₃ CO- <i>n</i> -C ₅ H ₁₁	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₅ H ₁₁)COH (76-77%)	191,47
CH ₃ CO- <i>n</i> -C ₅ H ₁₁	CH ₃ C≡CMgBr	CH ₃ (CH ₃ C≡C)(<i>n</i> -C ₅ H ₁₁)COH (71%)	94
CH ₃ CO- <i>n</i> -C ₅ H ₁₁	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>n</i> -C ₅ H ₁₁)COH (70%)	191,47
CH ₃ CO- <i>n</i> -C ₅ H ₁₁	<i>i</i> -C ₃ H ₇ MgCl	Carbinol (<i>none</i>); ketol (50%)	96
CH ₃ CO- <i>n</i> -C ₅ H ₁₁	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ (<i>n</i> -C ₄ H ₉)(<i>n</i> -C ₅ H ₁₁)COH (68%)	191,47
CH ₃ CO- <i>n</i> -C ₅ H ₁₁	CH ₃ CH=C(CH ₃)C≡CMgBr	CH ₃ (<i>n</i> -C ₅ H ₁₁)[CH ₃ CH=C(CH ₃)C≡C]COH (79%)	94
CH ₃ CO- <i>n</i> -C ₅ H ₁₁	<i>n</i> -C ₄ H ₉ C≡CMgBr	CH ₃ (<i>n</i> -C ₅ H ₁₁)(<i>n</i> -C ₄ H ₉ C≡C)COH (87%)	103
CH ₃ CO- <i>n</i> -C ₅ H ₁₁	C ₆ H ₅ C≡CMgBr	CH ₃ (<i>n</i> -C ₅ H ₁₁)(C ₆ H ₅ C≡C)COH (78%)	94
CH ₃ CO- <i>n</i> -C ₅ H ₁₁ (159.6 g., 1.4 mole)	C ₆ H ₅ (CH ₂) ₅ MgBr (319.5 g., 1.4 mole C ₁₁ H ₁₅ Br)	CH ₃ (<i>n</i> -C ₅ H ₁₁)[C ₆ H ₅ (CH ₂) ₅]COH (40.1%)	610
CH ₃ CO- <i>i</i> -C ₅ H ₁₁	CH ₃ MgI (50 g. CH ₃ I)	<i>i</i> -C ₅ H ₁₁ (CH ₃) ₂ COH (44 g.)	156
CH ₃ CO- <i>i</i> -C ₅ H ₁₁	C ₂ H ₅ MgBr (100 g. C ₂ H ₅ Br)	CH ₃ (C ₂ H ₅)(<i>i</i> -C ₅ H ₁₁)COH (61 g.)	163
CH ₃ COCH ₂ - <i>s</i> -C ₄ H ₉	CH ₃ MgI	<i>s</i> -C ₄ H ₉ CH ₂ (CH ₃) ₂ COH (90%)	162
CH ₃ COCH ₂ - <i>t</i> -C ₄ H ₉	CH ₃ MgBr	Addition (100%); enolization (0%)*	168
CH ₃ COCH ₂ - <i>t</i> -C ₄ H ₉ (3.1 moles)	C ₂ H ₅ MgBr (5.0 moles C ₂ H ₅ Br)	CH ₃ (C ₂ H ₅)(<i>t</i> -C ₄ H ₉ CH ₂)COH (359 g., crude)	159
CH ₃ COCH ₂ - <i>t</i> -C ₄ H ₉ (3.0 moles)	<i>n</i> -C ₃ H ₇ MgBr (4.5 moles C ₃ H ₇ Br)	CH ₃ (<i>n</i> -C ₃ H ₇)(<i>t</i> -C ₄ H ₉ CH ₂)COH (77 g., 0.49 mole); decenes (106 g., 0.76 mole); CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (5.5%); recovered ketone	159
CH ₃ COCH ₂ - <i>t</i> -C ₄ H ₉ (3.00 moles)	<i>n</i> -C ₄ H ₉ MgBr (3.17 moles)	CH ₃ (<i>n</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)COH (62.0%); CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (5.7%)	159
CH ₃ COCH ₂ - <i>t</i> -C ₄ H ₉ (3.00 moles)	<i>n</i> -C ₅ H ₁₁ MgBr (3.75 moles)	CH ₃ (<i>n</i> -C ₅ H ₁₁)(<i>t</i> -C ₄ H ₉ CH ₂)COH (222 g., crude); dodecenes (0.63 mole); CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (3.4%)	159

*“Grignard machine” study.

TABLE VI-XVIII (Continued)

Ketonic Comp'd	RMgX	Product(s)	Ref.
C₇H₁₄O (<i>cont.</i>)			
CH ₃ COCH(CH ₃)- <i>n</i> -C ₃ H ₇ (57 g.)	CH ₃ MgI (80 g. CH ₃ I)	CH ₃ (<i>n</i> -C ₃ H ₇)CH(CH ₃) ₂ COH (54 g.)	126
CH ₃ COCH(CH ₃)- <i>i</i> -C ₃ H ₇ (55 g.)	CH ₃ MgI (0.6 mole CH ₃ I)	CH ₃ (<i>i</i> -C ₃ H ₇)CH(CH ₃) ₂ COH (36 g., 51%)	190
CH ₃ CO- <i>t</i> -C ₃ H ₁₁	CH ₃ MgCl	<i>t</i> -C ₃ H ₁₁ (CH ₃) ₂ COH (65%)	170
CH ₃ CO- <i>t</i> -C ₅ H ₁₁	CH ₃ MgBr	Addition (74%); enolization (14%)*	168
C ₂ H ₅ CO- <i>t</i> -C ₄ H ₉	CH ₃ MgCl	Addition (86%); enolization (9%)*	168
C ₂ H ₅ CO- <i>t</i> -C ₄ H ₉	C ₆ H ₅ MgBr	C ₂ H ₅ (<i>t</i> -C ₄ H ₉)(C ₆ H ₅)COH (20%)	172, 234
(<i>n</i> -C ₃ H ₇) ₂ CO	(≡CMgBr) ₂	[≡CC(<i>n</i> -C ₃ H ₇) ₂ OH] ₂ (89%)	199, 21, 631
(<i>n</i> -C ₃ H ₇) ₂ CO (25 g.)	C ₂ H ₅ MgBr (8 g. Mg)	C ₂ H ₅ (<i>n</i> -C ₃ H ₇) ₂ COH (76%)	37
(<i>n</i> -C ₃ H ₇) ₂ CO	<i>n</i> -C ₃ H ₇ MgBr	(<i>n</i> -C ₃ H ₇) ₃ COH (35%); (<i>n</i> -C ₃ H ₇) ₂ CHOH (10%); C ₃ H ₆	193
(<i>n</i> -C ₃ H ₇) ₂ CO	<i>n</i> -C ₃ H ₇ MgBr	(<i>n</i> -C ₃ H ₇) ₃ COH (60%); (<i>n</i> -C ₃ H ₇) ₂ CHOH (20%)	37
(<i>n</i> -C ₃ H ₇) ₂ CO (0.5 mole)	<i>n</i> -C ₃ H ₇ MgBr (1.2 mole C ₃ H ₇ Br)	(<i>n</i> -C ₃ H ₇) ₃ COH (54%); (<i>n</i> -C ₃ H ₇) ₂ CHOH (24%)	194
(<i>n</i> -C ₃ H ₇) ₂ CO	<i>n</i> -C ₃ H ₇ MgI	(<i>n</i> -C ₃ H ₇) ₃ COH	157
(<i>n</i> -C ₃ H ₇) ₂ CO	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (<i>n</i> -C ₃ H ₇) ₂ COH	37
(<i>n</i> -C ₃ H ₇) ₂ CO	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (<i>n</i> -C ₃ H ₇) ₂ COH (44%); (<i>n</i> -C ₃ H ₇) ₂ CHOH (5%); enolization (15%)	194
(<i>n</i> -C ₃ H ₇) ₂ CO	2-Thienyl-MgI	α-C ₄ H ₃ S(<i>n</i> -C ₃ H ₇) ₂ COH	41
(<i>n</i> -C ₃ H ₇) ₂ CO	<i>i</i> -C ₄ H ₉ MgCl	<i>i</i> -C ₄ H ₉ (<i>n</i> -C ₃ H ₇) ₂ COH (20–25%)	195
(<i>n</i> -C ₃ H ₇) ₂ CO	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₅ H ₁₁ (<i>n</i> -C ₃ H ₇) ₂ COH	195
(<i>n</i> -C ₃ H ₇) ₂ CO	C ₆ H ₅ MgBr	C ₆ H ₅ (<i>n</i> -C ₃ H ₇) ₂ COH	195
(<i>n</i> -C ₃ H ₇) ₂ CO	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CH(<i>n</i> -C ₃ H ₇) ₂ COH	195
(<i>n</i> -C ₃ H ₇) ₂ CO	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ (<i>n</i> -C ₃ H ₇) ₂ COH	195
(<i>n</i> -C ₃ H ₇) ₂ CO	2-ClC ₆ H ₄ CH(CO ₂ MgCl)MgCl [†]	2-ClC ₆ H ₄ CH(CO ₂ H)C(<i>n</i> -C ₃ H ₇) ₂ OH	149
(<i>n</i> -C ₃ H ₇) ₂ CO	C ₆ H ₅ CH(CO ₂ Na)MgX [†]	C ₆ H ₅ CH(CO ₂ H)C(<i>n</i> -C ₃ H ₇) ₂ OH (88%)	200

*"Grignard machine" study.

[†]In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135–54 (1931), these "Grignard reagents" should be formulated as enolates.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₇H₁₄O (cont.)			
(<i>n</i> -C ₃ H ₇) ₂ CO	2-Methylindolyl-MgX	4,4-Bis-(2-methyl-3-indolyl)heptane	70
<i>n</i> -C ₃ H ₇ CO- <i>i</i> -C ₃ H ₇	<i>n</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (<i>n</i> -C ₃ H ₇) ₂ COH (63%); <i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇)CHOH (17%)	194
<i>n</i> -C ₃ H ₇ CO- <i>i</i> -C ₃ H ₇	<i>i</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇) ₂ COH (17%); <i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇)CHOH (49%)	194
(<i>i</i> -C ₃ H ₇) ₂ CO (25 g.)	CH ₃ MgBr (10 g. Mg)	CH ₃ (<i>i</i> -C ₃ H ₇) ₂ COH (78%)	37,196
(<i>i</i> -C ₃ H ₇) ₂ CO	(≡ CMgBr) ₂	[HO(<i>i</i> -C ₃ H ₇) ₂ C≡] ₂	199
(<i>i</i> -C ₃ H ₇) ₂ CO	(≡ CMgI) ₂	[HO(<i>i</i> -C ₃ H ₇) ₂ C≡] ₂	125
(<i>i</i> -C ₃ H ₇) ₂ CO	C ₂ H ₅ MgBr	C ₂ H ₅ (<i>i</i> -C ₃ H ₇) ₂ COH (77%); (<i>i</i> -C ₃ H ₇) ₂ CHOH (21%); recovered ketone (2%)*	196,37
(<i>i</i> -C ₃ H ₇) ₂ CO	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇) ₂ COH (35.8%); (<i>i</i> -C ₃ H ₇) ₂ CHOH (60.3%); recovered ketone (2%)*	196,37, 194,618
(<i>i</i> -C ₃ H ₇) ₂ CO + MgBr ₂	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇) ₂ CO (65%); (<i>i</i> -C ₃ H ₇) ₂ CHOH (26%); recovered ketone (3%)	618
(<i>i</i> -C ₃ H ₇) ₂ CO	<i>i</i> -C ₃ H ₇ MgBr	(<i>i</i> -C ₃ H ₇) ₃ COH (<i>none</i>); (<i>i</i> -C ₃ H ₇) ₂ CHOH (65%); recovered ketone (29%)*	196,37, 193,194
(<i>i</i> -C ₃ H ₇) ₂ CO	Butenyl-MgCl	CH ₃ (H ₂ C=CH)CH(<i>i</i> -C ₃ H ₇) ₂ COH (79.9%); CH ₃ CH=CHCH ₂ (<i>i</i> -C ₃ H ₇) ₂ COH (5.1%); octadienes	197
(<i>i</i> -C ₃ H ₇) ₂ CO	Butenyl-MgBr	CH ₃ (H ₂ C=CH)CH(<i>i</i> -C ₃ H ₇) ₂ COH (75.6%); CH ₃ CH=CHCH ₂ (<i>i</i> -C ₃ H ₇) ₂ COH (13.4%); octadienes	197
(<i>i</i> -C ₃ H ₇) ₂ CO	<i>i</i> -C ₄ H ₉ MgBr	<i>i</i> -C ₄ H ₉ (<i>i</i> -C ₃ H ₇) ₂ COH (7.9%); (<i>i</i> -C ₃ H ₇) ₂ CHOH (78.2%); recovered ketone (10.6%)*	196

*The amount of recovered ketone is interpreted as indicative of the extent of enolization. However, this can be correct in general only when ketolization is negligible (see Grignard Condensations of Aldehydes and Ketones, p. 176).

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₄O (<i>cont.</i>)			
(<i>i</i> -C ₃ H ₇) ₂ CO	<i>t</i> -C ₄ H ₉ CH ₂ MgCl	<i>t</i> -C ₄ H ₉ CH ₂ (<i>i</i> -C ₃ H ₇) ₂ COH (4%); (<i>i</i> -C ₃ H ₇) ₂ CHOH (<i>none</i>); recovered ketone (90%)*	196
(<i>i</i> -C ₃ H ₇) ₂ CO (25 g.)	C ₆ H ₅ MgBr (10 g. Mg)	C ₆ H ₅ (<i>i</i> -C ₃ H ₇) ₂ COH (24 g.)	37
(<i>i</i> -C ₃ H ₇) ₂ CO	<i>n</i> -C ₄ H ₉ C≡CMgBr	<i>n</i> -C ₄ H ₉ C≡C(<i>i</i> -C ₃ H ₇) ₂ COH (68%)	94
C₇H₁₄O₂			
CH ₃ COCH ₂ CH(OH) <i>n</i> -C ₂ H ₇	CH ₃ MgI	HO(CH ₃) ₂ CCH ₂ CH(OH)- <i>n</i> -C ₃ H ₇ (90%)	183
CH ₃ COCH ₂ CH(OH) <i>n</i> -C ₃ H ₇	C ₂ H ₅ MgBr	HO(CH ₃) (C ₂ H ₅)CCH ₂ CH(OH)- <i>n</i> -C ₃ H ₇	183
CH ₃ COCH ₂ CH(OH)- <i>n</i> -C ₃ H ₇	C ₆ H ₅ MgBr	HO(CH ₃) (C ₆ H ₅)CCH ₂ CH(OH)- <i>n</i> -C ₃ H ₇	183
C ₂ H ₅ OCH ₂ CO- <i>n</i> -C ₃ H ₇	C ₂ H ₅ MgBr	C ₂ H ₅ (C ₂ H ₅ OCH ₂) (<i>n</i> -C ₃ H ₇)COH	198
C ₂ H ₅ OCH ₂ CO- <i>n</i> -C ₃ H ₇	<i>i</i> -C ₅ H ₁₁ MgX	C ₂ H ₅ OCH ₂ (<i>n</i> -C ₃ H ₇) (<i>i</i> -C ₅ H ₁₁)COH	198
C₇H₁₄O₃			
[HO(CH ₃) ₂ C] ₂ CO (20 g.)	CH ₃ MgI	[HO(CH ₃) ₂ C] ₂ C(OH)CH ₃ (114 g., 64%); CH ₄ (6 l.)	620
C₇H₁₅ON			
CH ₃ COCH ₂ N(C ₂ H ₅) ₂	2-C ₆ H ₅ C ₆ H ₄ MgI	CH ₃ [(C ₂ H ₅) ₂ NCH ₂] (2-C ₆ H ₅ C ₆ H ₄)COH	16
C₈H₅OF₃			
F ₃ CCOC ₆ H ₅	C ₆ H ₅ MgBr	F ₃ C(C ₆ H ₅) ₂ COH (46%)	209
C₈H₅ON			
NCCOC ₆ H ₅	C ₂ H ₅ MgBr	C ₂ H ₅ C(=NH·HCN)COC ₆ H ₅ ; C ₆ H ₅ (C ₂ H ₅) ₂ COH	202
NCCOC ₆ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ COH	202
NCCOC ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ (C ₆ H ₅ CH ₂) ₂ COH	202

*The amount of recovered ketone is interpreted as indicative of the extent of enolization. However, this can be correct in general only when ketolization is negligible (see Grignard Condensations of Aldehydes and Ketones, p. 176).

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₈H₆O₂			
CHOCOC ₆ H ₅ (5 g.)	C ₆ H ₅ MgBr (4 g. C ₆ H ₅ Br)	C ₆ H ₅ CH(OH)C(C ₆ H ₅) ₂ OH (4 g., crude)	203
C₈H₇OBr			
CH ₃ COC ₆ H ₄ -3-Br (567 g., 2.85 moles)	C ₂ H ₅ MgBr (3.2 moles)	CH ₃ (3-BrC ₆ H ₄)C=CH ₂ (420 g., 70%)	210
C₈H₇OCl			
ClCH ₂ COC ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	No <i>ortho</i> -substitution; actual product (s) not identified	204
CH ₃ COC ₆ H ₄ -2-Cl	4-CH ₃ C ₁₀ H ₆ -1-MgBr	CH ₃ (2-ClC ₆ H ₄)(4-CH ₃ C ₁₀ H ₆ -1-COH) (<i>ca.</i> 37%); 1-CH ₃ C ₁₀ H ₇ ; recovered ketone	205
CH ₃ COC ₆ H ₄ -2-Cl	8-CH ₃ C ₁₀ H ₆ -1-MgBr	CH ₃ (2-ClC ₆ H ₄)(8-CH ₃ C ₁₀ H ₆ -1-)COH (<i>ca.</i> 20%)	205
C₈H₇OI			
CH ₃ COC ₆ H ₄ -4-I	C ₂ H ₃ MgI	CH ₃ (4-IC ₆ H ₄)C=CHCH ₃	206
C₈H₇ON₃			
N ₃ CH ₂ COC ₆ H ₅	C ₆ H ₅ MgBr (2 equiv.)	C ₆ H ₅ NHN=NCH ₂ (C ₆ H ₅) ₂ COH (50%)	211
C₈H₇O₂N			
HON=CHCOC ₆ H ₅ (30.0 g.)	C ₂ H ₅ MgBr (87.2 g. C ₂ H ₅ Br)	HON=CH ₂ (C ₂ H ₅)(C ₆ H ₅)COH (28%)	17
HON=CHCOC ₆ H ₅ (50 g.)	<i>n</i> -C ₄ H ₉ MgBr (220 g. C ₄ H ₉ Br)	HON=CH ₂ (<i>n</i> -C ₄ H ₉)(C ₆ H ₅)COH (90 g., crude)	17
HON=CHCOC ₆ H ₅ (15 g.)	C ₆ H ₅ MgBr (80 g. C ₆ H ₅ Br)	HON=CH ₂ (C ₆ H ₅) ₂ COH (75%)	207, 17, 208
HON=CHCOC ₆ H ₅ (30 g.)	4-CH ₃ C ₆ H ₄ MgBr (136 g. C ₇ H ₇ Br)	HON=CH ₂ (C ₆ H ₅)(4-CH ₃ C ₆ H ₄)COH (54 g., crude)	17
C₈H₆O			
CH ₃ COC ₆ H ₅	CH ₃ MgI	C ₆ H ₅ (CH ₃) ₂ COH (65%); CH ₃ (C ₆ H ₅)C=CH ₂ (21%)	18, 61, 206, 212

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₅O (cont.)			
CH ₃ COC ₆ H ₅	(≡CMgBr) ₂	[≡CC(CH ₃)(C ₆ H ₅)OH] ₂ (ca. quant.)	22,21,199
CH ₃ COC ₆ H ₅	(≡CMgI) ₂	[≡CC(CH ₃)(C ₆ H ₅)OH] ₂	125
CH ₃ COC ₆ H ₅	HC≡CMgBr	CH ₃ (HC≡C)(C ₆ H ₅)COH (26%)	214
CH ₃ COC ₆ H ₅	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)(C ₆ H ₅)COH	215
CH ₃ COC ₆ H ₅	C ₂ H ₅ MgI	CH ₃ (C ₆ H ₅)C=CHCH ₃	206
CH ₃ COC ₆ H ₅	H ₂ C=CHCH ₂ MgBr	CH ₃ (H ₂ C=CHCH ₂)(C ₆ H ₅)COH	216,28
CH ₃ COC ₆ H ₅	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅)COH	619
CH ₃ COC ₆ H ₅	<i>n</i> -C ₃ H ₇ MgI	CH ₃ (C ₆ H ₅)C=CHC ₂ H ₅	206
CH ₃ COC ₆ H ₅	2-Thienyl-MgI	CH ₃ (<i>α</i> -C ₄ H ₃ S)(C ₆ H ₅)COH	41
CH ₃ COC ₆ H ₅	Pyrryl-MgX	1,1-Bis-(2-pyrryl)-1-phenylethane; <i>α</i> -(2-pyrryl)- <i>α</i> -phenylethanol	70
CH ₃ COC ₆ H ₅ (21.5 g.)	C ₂ H ₅ OC≡CMgBr (12 g. C ₂ H ₅ OC≡CH)	CH ₃ (C ₂ H ₅ OC≡C)(C ₆ H ₅)COH (15 g.); recovered ketone (4 g.)	233
CH ₃ COC ₆ H ₅	C ₂ H ₅ OC≡CMgBr	CH ₃ (C ₂ H ₅ OC≡C)(C ₆ H ₅)COH (97.7%)	43
CH ₃ COC ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ (<i>n</i> -C ₄ H ₉)(C ₆ H ₅)COH	217
CH ₃ COC ₆ H ₅	<i>i</i> -C ₄ H ₉ MgI	CH ₃ (<i>i</i> -C ₄ H ₉)(C ₆ H ₅)COH; CH ₃ (C ₆ H ₅)C=CH- <i>i</i> -C ₃ H ₇ ; recovered ketone	146
CH ₃ COC ₆ H ₅ (22 g.)	2-Pyridyl-MgBr	CH ₃ (<i>α</i> -C ₅ H ₄ N)(C ₆ H ₅)COH (2.5 g., crude)	218
CH ₃ COC ₆ H ₅ (120 g.)	<i>n</i> -C ₅ H ₁₁ MgBr (151 g. C ₅ H ₁₁ Br)	CH ₃ (<i>n</i> -C ₅ H ₁₁)(C ₆ H ₅)COH (58 g.)	100
CH ₃ COC ₆ H ₅	<i>i</i> -C ₅ H ₁₁ MgI	CH ₃ (<i>i</i> -C ₅ H ₁₁)(C ₆ H ₅)COH; CH ₃ (C ₆ H ₅)C=CH- <i>i</i> -C ₄ H ₉	146,206
CH ₃ COC ₆ H ₅ (1 mole)	DL- <i>s</i> -C ₄ H ₉ CH ₂ MgBr	CH ₃ (C ₂ H ₅)CHCH ₂ (C ₆ H ₅)(CH ₃)COH (27 g.); recovered ketone (62 g.)*	100
CH ₃ COC ₆ H ₅	C ₆ H ₅ MgBr	CH ₃ (C ₆ H ₅) ₂ COH (yielding 58% olefin)	180,213, 219
CH ₃ COC ₆ H ₅	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CH(CH ₃)(C ₆ H ₅)COH (50%)	59,58

*Attributed to enolization.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₅O (<i>cont.</i>)			
CH ₃ COC ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	CH ₃ (C ₆ H ₅)(C ₆ H ₅ CH ₂)COH (92%)	199,220
CH ₃ COC ₆ H ₅	C ₆ H ₅ CH ₂ Cl + Mg	CH ₃ (C ₆ H ₅)(C ₆ H ₅ CH ₂)COH; CH ₃ (C ₆ H ₅)C≡CHC ₆ H ₅	104
CH ₃ COC ₆ H ₅	4-CH ₃ C ₆ H ₄ MgBr	CH ₃ (C ₆ H ₅)(4-CH ₃ C ₆ H ₄)COH (yielding 48-60% olefin)	180
CH ₃ COC ₆ H ₅	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	CH ₃ (C ₆ H ₅)[(C ₂ H ₅) ₂ N(CH ₂) ₃]COH	226
CH ₃ COC ₆ H ₅	C ₆ H ₅ CH(CO ₂ Na)MgX*	CH ₃ (C ₆ H ₅)[C ₆ H ₅ CH(CO ₂ H)]COH ("good yield")	200
CH ₃ COC ₆ H ₅	1-Indenyl-MgBr	CH ₃ (C ₆ H ₅)(1-C ₉ H ₇)COH; "some" dehydr'n product	69
CH ₃ COC ₆ H ₅	2-Methylindolyl-MgX (2 equiv.)	1,1-Bis-(2-methyl-3-indolyl)-1-phenylethane	70
CH ₃ COC ₆ H ₅ (20 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (41 g. C ₉ H ₁₁ Br)	2,4,6-(CH ₃) ₃ C ₆ H ₂ (C ₆ H ₅)C≡CH ₂ (3 g.); re-covered ketone (12 g.); (CH ₃) ₃ C ₆ H ₃ (12 g.)	221
CH ₃ COC ₆ H ₅	1-C ₁₀ H ₇ MgBr	CH ₃ (C ₆ H ₅)(1-C ₁₀ H ₇)COH (yielding 51% olefin)	180,227
CH ₃ COC ₆ H ₅	2,3,4,6-(CH ₃) ₄ C ₆ HMgBr	2,3,4,6-(CH ₃) ₄ C ₆ H(C ₆ H ₅)C≡CH ₂ (10%)	221
CH ₃ COC ₆ H ₅ (42 g.)	2,3,5,6-(CH ₃) ₄ C ₆ HMgBr (5 g. C ₁₀ H ₁₃ Br)	2,3,5,6-(CH ₃) ₄ C ₆ H(C ₆ H ₅)C≡CH ₂ (3.5 g.); enolization (80%)	228
CH ₃ COC ₆ H ₅	Isobornyl-MgCl	CH ₃ (C ₆ H ₅)CHOH, [α] ₅₇₈ 20.10° [†] (55%)	230,229
CH ₃ COC ₆ H ₅	<i>n</i> -C ₁₂ H ₂₅ MgBr	CH ₃ (C ₆ H ₅)(<i>n</i> -C ₁₂ H ₂₅)COH; C ₂₂ H ₃₂	222
CH ₃ COC ₆ H ₅ (12.5 g.)	9-Phenanthryl-MgBr (25.7 ml. C ₁₄ H ₉ Br)	9-C ₁₄ H ₉ (CH ₃)(C ₆ H ₅)COH (yielding 4.5 g. olefin)	617
CH ₃ COC ₆ H ₅	(C ₆ H ₅) ₂ C=CHMgBr	(C ₆ H ₅) ₂ C=CH(C ₆ H ₅)(CH ₃)COH	223
CH ₃ COC ₆ H ₅ (288 g., 2.4 moles)	<i>n</i> -C ₁₈ H ₃₇ MgBr (750 g., 2.25 moles C ₁₈ H ₃₇ Br)	CH ₃ (C ₆ H ₅)(<i>n</i> -C ₁₈ H ₃₇)COH (yielding 896 g. crude olefins)	231

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

[†]For the pure enantiomorph, [α]₅₇₈ 54.86°.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₈H₈O₂			
HOCH ₂ COC ₆ H ₅ (11 g.)	CH ₃ MgI (25 g. CH ₃ I)	HOCH ₂ (CH ₃)(C ₆ H ₅)COH	225
HOCH ₂ COC ₆ H ₅	C ₂ H ₅ MgX (2 equiv.)	HOCH ₂ (C ₂ H ₅)(C ₆ H ₅)COH (15.4%); 2,5-diethyl- 2,5-diphenyl-1,4-dioxane (29.8%)	225
HOCH ₂ COC ₆ H ₅ (13.6 g.)	C ₆ H ₅ MgBr (31.4 g. C ₆ H ₅ Br)	HOCH ₂ (C ₆ H ₅) ₂ COH	225
Furfurylideneacetone (80 g.)	C ₂ H ₅ MgBr (120 g. C ₂ H ₅ Br)	CH ₃ COCH ₂ CH(α -C ₄ H ₃ O)C ₂ H ₅ (50 g., 50%); high-boiling residue	599
Furfurylidenaacetone (50 g.)	<i>n</i> -C ₃ H ₇ MgBr (100 g. C ₃ H ₇ Br)	CH ₃ COCH ₂ CH(α -C ₄ H ₃ O)- <i>n</i> -C ₃ H ₇ (50%)	599
Furfurylideneacetone (80 g.)	<i>i</i> -C ₃ H ₇ MgBr (130 g. C ₃ H ₇ Br)	CH ₃ COCH ₂ CH(α -C ₄ H ₃ O)- <i>i</i> -C ₃ H ₇ (65 g., 61%)	599
Furfurylideneacetone (60 g.)	<i>i</i> -C ₄ H ₉ MgBr (145 g. C ₄ H ₉ Br)	CH ₃ COCH ₂ CH(α -C ₄ H ₃ O)- <i>i</i> -C ₄ H ₉	599
Furfurylideneacetone	<i>i</i> -C ₅ H ₁₁ MgI	CH ₃ COCH ₂ CH(α -C ₄ H ₃ O)- <i>i</i> -C ₅ H ₁₁ (44%)	224
Furfurylideneacetone	C ₆ H ₅ MgBr	High-boiling cond'n products	140
C₈H₉ON			
2-Acetyl-5-methylpyridine	CH ₃ MgI	Dimethyl-(5-methyl-2-pyridyl)methanol	235
C₈H₁₀OBrN			
HBr·H ₂ NCH ₂ COC ₆ H ₅	<i>n</i> -C ₄ H ₉ MgI	H ₂ NCH ₂ (<i>n</i> -C ₄ H ₉)(C ₆ H ₅)COH	236
HBr·H ₂ NCH ₂ COC ₆ H ₅	(CH ₂) ₅ CHMgCl	H ₂ NCH ₂ (C ₆ H ₅)[(CH ₂) ₅ CH]COH	236
C₈H₁₀OCIN			
HCl·H ₂ NCH ₂ COC ₆ H ₅ (5 g.)	4-CH ₃ C ₆ H ₄ MgBr (30 g. C ₇ H ₇ Br)	H ₂ NCH ₂ (C ₆ H ₅)(4-CH ₃ C ₆ H ₄)COH (4.5 g.)	238
C₈H₁₂O			
CH ₃ COC \equiv C- <i>n</i> -C ₄ H ₉ (3.5 g.)	<i>n</i> -C ₄ H ₉ C \equiv CMgBr (2.7 g. <i>n</i> -C ₄ H ₉ C \equiv CH)	CH ₃ (<i>n</i> -C ₄ H ₉ C \equiv C) ₂ COH (1.9 g.); recovered ketone (1.0 g.)	83
C₈H₁₂O₃			
CH ₃ COC(CO ₂ C ₂ H ₅)=CHCH ₃	CH ₃ MgI (1 equiv.)	Recovered ketone; CH ₃ CO- <i>i</i> -C ₄ H ₉ *	151

*Dropwise addition of ketone to Grignard reagent solution.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₂O₅ (cont.)			
CH ₃ COC(CO ₂ C ₂ H ₅)=CHCH ₃	CH ₃ MgI (1 equiv.)	Condens'n products chiefly; recovered ketone; CH ₃ CO- <i>i</i> -C ₄ H ₉ (trace)*	151
C₆H₁₃OCl			
CH ₃ COCCL(CH ₂) ₅	CH ₃ MgX	CH ₃ COC(CH ₃)(CH ₂) ₅ ; no chlorohydrin isolable	237
CH ₃ COCCL(CH ₂) ₅	C ₆ H ₅ MgX	CH ₃ COC(C ₆ H ₅)(CH ₂) ₅ ; no chlorohydrin isolable	237
C₈H₁₄O			
CH ₃ CO(CH ₂) ₂ CH=C(CH ₃) ₂ (39.2 g.)	CH ₃ MgI (45.0 g. CH ₃ I)	(CH ₃) ₂ C=CHCH ₂ CH ₂ (CH ₃) ₂ COH (44.2 g., crude)	244, 134, 242
CH ₃ CO(CH ₂) ₂ CH=C(CH ₃) ₂ (100 g.)	CH ₃ I (113 g.) + Mg (20 g.)	(CH ₃) ₂ C=CHCH ₂ CH ₂ (CH ₃) ₂ COH	243
CH ₃ CO(CH ₂) ₂ CH=C(CH ₃) ₂	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)[(CH ₃) ₂ C=CHCH ₂ CH ₂]COH (82%)	242
CH ₃ CO(CH ₂) ₂ CH=C(CH ₃) ₂	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)[(CH ₃) ₂ C=CHCH ₂ CH]COH (85%)	242
CH ₃ CO(CH ₂) ₂ CH=C(CH ₃) ₂	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ (<i>i</i> -C ₃ H ₇)[(CH ₃) ₂ C=CHCH ₂ CH ₂]COH ("poor yield")	242
CH ₃ CO(CH ₂) ₂ CH=C(CH ₃) ₂ (7.5 g.)	C ₂ H ₅ OC≡CMgBr (6.3 g. C ₂ H ₅ OC≡CH)	CH ₃ (C ₂ H ₅ OC≡C)[(CH ₃) ₂ C=CHCH ₂ CH ₂]COH (8.5 g., 73%)	233
CH ₃ CO(CH ₂) ₂ CH=C(CH ₃) ₂	<i>n</i> -C ₅ H ₉ MgBr	CH ₃ (<i>n</i> -C ₄ H ₉)[(CH ₃) ₂ C=CHCH ₂ CH ₂]COH (65%)	242
CH ₃ CO(CH ₂) ₂ CH=C(CH ₃) ₂	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>i</i> -C ₅ H ₁₁)[(CH ₃) ₂ C=CHCH ₂ CH ₂]COH (70%)	242
CH ₃ CO(CH ₂) ₂ CH=C(CH ₃) ₂	C ₆ H ₅ MgBr	CH ₃ (C ₆ H ₅)[(CH ₃) ₂ C=CHCH ₂ CH ₂]COH (55%)	242
CH ₃ CO(CH ₂) ₂ CH=C(CH ₃) ₂	C ₆ H ₅ CH ₂ MgCl	CH ₃ (C ₆ H ₅ CH ₂)[(CH ₃) ₂ C=CHCH ₂ CH ₂]COH (45%)	242

*Gradual addition of Grignard reagent solution to ketone.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₄O (<i>cont.</i>)			
CH ₃ CO(CH ₂) ₂ CH=C(CH ₃) ₂	C ₆ H ₅ C≡CMgBr	CH ₃ [(CH ₃) ₂ C=CHCH ₂ CH ₂](C ₆ H ₅ C≡C)COH (<i>ca.</i> 75%)	36
CH ₃ COCH(CH ₂) ₅	CH ₃ MgBr	(CH ₂) ₅ CH(CH ₃) ₂ COH (56%)	212
CH ₃ COC(CH ₃)=CH- <i>n</i> -C ₃ H ₇ (40 g.)	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)[<i>n</i> -C ₃ H ₇ CH=C(CH ₃)]COH (15 g.); CH ₃ COCH(CH ₃)CH(C ₂ H ₅)- <i>n</i> -C ₃ H ₇ (yielding 3 g., 20% semi-carbazone)	150
CH ₃ COC(CH ₃)=C(CH ₃)C ₂ H ₅	CH ₃ MgI	CH ₃ (C ₂ H ₅)C=(CH ₃)C(CH ₃) ₂ COH (63%)	150
CH ₃ COC(CH ₃)=C(CH ₃)C ₂ H ₅	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)[CH ₃ (C ₂ H ₅)C=(CH ₃)C]COH (60%)	150
CH ₃ COC(CH ₃)=C(CH ₃)C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)[CH ₃ (C ₂ H ₅)C=(CH ₃)C]COH (38%)	150
CH ₃ COC(CH ₃)=C(CH ₃)C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ (<i>n</i> -C ₄ H ₉)[CH ₃ (C ₂ H ₅)C=(CH ₃)C]COH (38%)	150
C ₂ H ₅ COCH=CH- <i>n</i> -C ₃ H ₇ (40 g.)	C ₂ H ₅ MgBr (60 g. C ₂ H ₅ Br)	<i>n</i> -C ₃ H ₇ CH=CH(C ₂ H ₅) ₂ COH (yielding 38.6% diene)	184
C ₂ H ₅ COCH=C(CH ₃)C ₂ H ₅ (20 g.)	C ₂ H ₅ MgBr (20 g. C ₂ H ₅ Br)	CH ₃ (C ₂ H ₅)C=CH(C ₂ H ₅) ₂ COH (yielding 52.9% diene)*	184
C ₂ H ₅ COCH=C(CH ₃)C ₂ H ₅ (12.6 g.)	C ₂ H ₅ MgBr (11.0 g. C ₂ H ₅ Br)	CH ₃ (C ₂ H ₅)C=CH(C ₂ H ₅) ₂ COH (yielding 31.5% diene) [†]	239
C ₂ H ₅ COCH=C(CH ₃)C ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ [CH ₃ (C ₂ H ₅)C=CH](<i>i</i> -C ₅ H ₁₁)COH	239
(CH ₂) ₂ CHCO- <i>n</i> -C ₄ H ₉	CH ₃ MgBr	CH ₃ [(CH ₂) ₂ CH](<i>n</i> -C ₄ H ₉)COH	115
(CH ₂) ₂ CHCO- <i>n</i> -C ₄ H ₉	<i>n</i> -C ₄ H ₉ MgBr	(CH ₂) ₂ CH(<i>n</i> -C ₄ H ₉) ₂ COH	115
(CH ₂) ₂ CHCO- <i>n</i> -C ₄ H ₉	<i>n</i> -C ₅ H ₁₁ MgBr	(CH ₂) ₂ CH(<i>n</i> -C ₄ H ₉)(<i>n</i> -C ₅ H ₁₁)COH	115
(CH ₂) ₂ CHCO- <i>i</i> -C ₄ H ₉	C ₂ H ₅ MgBr	C ₂ H ₅ [(CH ₂) ₂ CH](<i>n</i> -C ₄ H ₉)COH	240
(CH ₂) ₂ CHCO- <i>i</i> -C ₄ H ₉	<i>n</i> -C ₃ H ₇ MgBr	(CH ₂) ₂ CH(<i>n</i> -C ₃ H ₇)(<i>i</i> -C ₄ H ₉)COH	240

*Slow reverse addition at -14°.

[†]Slow reverse addition at room temperature; sixteen hours standing.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₄O₂			
CH ₃ O(CH ₂) ₂ COCH=C(CH ₃) ₂ (126 g.)	CH ₃ MgI (140 g. CH ₃ I)	CH ₃ OCH ₂ CH ₂ C(=CH ₂)CH=C(CH ₃) ₂ + CH ₃ OCH ₂ CH=C(CH ₃)CH=C(CH ₃) ₂ (totaling 39 g.)	245
(<i>i</i> -C ₃ H ₇ CO—) ₂ (35.5 g.)	C ₂ H ₅ MgI (56.0 g. C ₂ H ₅ I)	HO(C ₂ H ₅)(<i>i</i> -C ₃ H ₇)CCO- <i>i</i> -C ₃ H ₇ (30%)	246
C₈H₁₄O₃			
CH ₃ COCO ₂ - <i>i</i> -C ₅ H ₁₁	CH ₃ MgI (1 equiv.)	HO(CH ₃) ₂ CCO ₂ - <i>i</i> -C ₅ H ₁₁ (25%)	151,187
CH ₃ COCO ₂ - <i>i</i> -C ₅ H ₁₁	<i>i</i> -C ₅ H ₁₁ MgBr (1 equiv.)	HO(CH ₃)(<i>i</i> -C ₅ H ₁₁)CCO ₂ - <i>i</i> -C ₅ H ₁₁ (25%)	151,187
CH ₃ COCO ₂ - <i>i</i> -C ₅ H ₁₁	I-C ₁₀ H ₇ MgBr (1 equiv.)	HO(CH ₃)(1-C ₁₀ H ₇)CCO ₂ - <i>i</i> -C ₅ H ₁₁ (25%)	151,187
CH ₃ COCH(C ₂ H ₅)CO ₂ C ₂ H ₅	CH ₃ MgI (1 equiv.)	HO(CH ₃) ₂ CCH(C ₂ H ₅)CO ₂ C ₂ H ₅ ("very little"); recovered ketone	151,152
CH ₃ COCH(C ₂ H ₅)CO ₂ C ₂ H ₅ (53 g.)	CH ₃ MgI (3 equiv.)	[HO(CH ₃) ₂ C] ₂ CHC ₂ H ₅ ("very poor yield"); HO(CH ₃) ₂ CCH(C ₂ H ₅)CO ₂ C ₂ H ₅ ("probably a little"); recovered ketone (<i>ca.</i> 30 g.)	151,152
CH ₃ COC(CH ₃) ₂ CO ₂ C ₂ H ₅	CH ₃ MgI	[HO(CH ₃) ₂ C] ₂ C(CH ₃) ₂	247
C₈H₁₆O			
CH ₃ CO- <i>n</i> -C ₆ H ₁₃	CH ₃ MgCl	<i>n</i> -C ₆ H ₁₃ (CH ₃) ₂ COH (85%)	128,248
CH ₃ CO- <i>n</i> -C ₆ H ₁₃	(≡CMgI) ₂	[≡CC(CH ₃)(<i>n</i> -C ₆ H ₁₃)OH] ₂	125
CH ₃ CO- <i>n</i> -C ₆ H ₁₃ (9.4 moles)	<i>n</i> -C ₂ H ₅ MgBr (11.0 moles C ₂ H ₅ Br)	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₆ H ₁₃)COH (77%)	249,248
CH ₃ COCH(CH ₃)- <i>t</i> -C ₄ H ₉	CH ₃ MgCl	Addition (47%); enolization (48%)*	124
CH ₃ COC(C ₂ H ₅) ₂ CH ₃	CH ₃ MgBr	Addition (0%); enolization (84%)*	168
D(+)-C ₂ H ₅ COCH ₂ CH(CH ₃)C ₂ H ₅	CH ₃ MgX	CH ₃ (C ₂ H ₅)[CH ₃ (C ₂ H ₅)CHCH ₂]COH	250
<i>n</i> -C ₃ H ₇ CO- <i>s</i> -C ₄ H ₉	CH ₃ MgCl	Addition (40%); enolization (53%)*	124
<i>i</i> -C ₃ H ₇ CO- <i>i</i> -C ₄ H ₉	(≡CMgBr) ₂	[≡CC(<i>i</i> -C ₃ H ₇)(<i>i</i> -C ₄ H ₉)OH] ₂ (81%)	199
<i>i</i> -C ₃ H ₇ CO- <i>t</i> -C ₄ H ₉	CH ₃ MgCl	Addition (49%); enolization (0%)*	124

* "Grignard machine" study.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₆O (<i>cont.</i>)			
<i>i</i> -C ₃ H ₇ CO- <i>t</i> -C ₄ H ₉ (0.29 mole)	Butenyl-MgBr (1 equiv.)	<i>i</i> -C ₅ H ₇ [CH ₃ (H ₂ C=CH)CH](<i>t</i> -C ₄ H ₉)COH (74%)	251
C₈H₁₆O₂			
<i>n</i> -C ₃ H ₇ COCH(OH)- <i>n</i> -C ₃ H ₇ (36 g.)	C ₆ H ₅ MgBr (170 g. C ₆ H ₅ Br)	<i>n</i> -C ₅ H ₇ [<i>n</i> -C ₃ H ₇ CH(OH)](C ₆ H ₅)COH (<i>ca.</i> 47 g.)	252
C₈H₁₇ON			
CH ₃ CO(CH ₂) ₂ N(C ₂ H ₅) ₂	RMgBr*	(C ₂ H ₅) ₂ N(CH ₂) ₂ CR(CH ₃)OH* (15-33%)	253
C₉H₄OBr₂S₂			
Bis-(5-Bromo-2-thienyl) ketone	C ₆ H ₅ CH ₂ MgCl	Product dec. on dist'n	254
C₉H₆OS₂			
Bis-2-thienyl ketone (6 g.)	C ₆ H ₅ CH ₂ MgCl (5 g. C ₇ H ₇ Cl)	Carbinol [yielding 4.5 g. crude C ₆ H ₅ CH=C(α-C ₄ H ₃ S) ₂]	254
C₉H₈O			
H ₂ C=CHCOC ₆ H ₅	CH ₃ MgI	<i>n</i> -C ₃ H ₇ COC ₆ H ₅ ; <i>no</i> carbinol	256
H ₂ C=CHCOC ₆ H ₅ (38.1 g., 0.29 mole)	Butenyl-MgBr (0.29 mole)	"Polymeric" material	255
H ₂ C=CHCOC ₆ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ (CH ₂) ₂ COC ₆ H ₅ ; <i>no</i> carbinol	256
C₉H₆O₂Cl₂			
C ₂ H ₅ COC ₆ H ₄ -2-OH-3,5-Cl ₂ (7.82 g.)	2-C ₆ H ₅ C ₆ H ₄ MgI (2 ml. C ₁₂ H ₉ I)	C ₂ H ₅ (2-HO-3,5-Cl ₂ C ₆ H ₂)(2-C ₆ H ₅ C ₆ H ₄)COH (6.5 g., 49%)	257
C₉H₈O₂N			
CH ₃ COC(=NOH)C ₆ H ₅ (16.3 g.)	C ₆ H ₅ MgBr (63 g. C ₆ H ₅ Br)	CH ₃ (C ₆ H ₅)[C ₆ H ₅ (HON=C)]COH (71%)	207

*R = C₆H₅, 1-C₁₀H₇, 2-C₁₀H₇, 4-CH₃O-1-C₁₀H₆, 9-Phenanthryl.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₀O			
CH ₃ COCH ₂ C ₆ H ₅ (134 g.)	C ₂ H ₅ MgBr (136 g. C ₂ H ₅ Br)	CH ₃ (C ₂ H ₅)(C ₆ H ₅ CH ₂)COH	252
CH ₃ COC ₆ H ₄ -4-CH ₃	2-Methylindolyl-MgX	1,1-Bis-(2-methyl-3-indolyl)-1-p-tolyethane	70
C ₂ H ₅ COC ₆ H ₅	<i>n</i> -C ₃ H ₇ MgI	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅)COH (yielding 72% 3-phenylhexane upon dehydr'n and hydrogen'n)	259
C ₂ H ₅ COC ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	C ₂ H ₅ (C ₆ H ₅)(C ₆ H ₅ CH ₂)COH	260, 199
C ₂ H ₅ COC ₆ H ₅	C ₆ H ₅ (CH ₂) ₃ MgCl	C ₂ H ₅ (C ₆ H ₅)[C ₆ H ₅ (CH ₂) ₃]COH (64%)	261
C ₂ H ₅ COC ₆ H ₅	Isobornyl-MgCl*	C ₂ H ₅ (C ₆ H ₅)CHOH, [α] _D 10.60° (50%) [†]	230
C₉H₁₀O₂			
CH ₃ COCH ₂ OC ₆ H ₅	2-C ₆ H ₅ C ₆ H ₄ MgI	CH ₃ (C ₆ H ₅ OCH ₂)(2-C ₆ H ₅ C ₆ H ₄)COH	16
CH ₃ COCH(OH)C ₆ H ₅	CH ₃ MgBr	HO(CH ₃) ₂ CCH(OH)C ₆ H ₅ ; CH ₃ [CH ₃ (HO)CH](C ₆ H ₅)COH [†]	258
CH ₃ COCH(OH)C ₆ H ₅ (6 g.)	C ₂ H ₅ MgBr (13 g. C ₂ H ₅ Br)	HO(CH ₃)(C ₂ H ₅)CCH(OH)C ₆ H ₅ (3 g., crude)	179
CH ₃ COCH(OH)C ₆ H ₅	C ₆ H ₅ MgBr	HO(CH ₃)(C ₆ H ₅)CCH(OH)C ₆ H ₅	258
CH ₃ CH(OH)COC ₆ H ₅	CH ₃ MgBr	CH ₃ [CH ₃ (HO)CH](C ₆ H ₅)COH	258
CH ₃ CH(OH)COC ₆ H ₅	C ₆ H ₅ MgBr	CH ₃ (HO)CH(C ₆ H ₅) ₂ COH; HO(CH ₃)(C ₆ H ₅)CCH(OH)C ₆ H ₅ [†]	258
C₉H₁₂OCIN			
CH ₃ CH(NH ₂ ·HCl)COC ₆ H ₅ (6 g.)	CH ₃ MgI (6 equiv.)	CH ₃ [CH ₃ (HCl·H ₂ N)CH](C ₆ H ₅)COH (5.5 g.)	262
CH ₃ CH(NH ₂ ·HCl)COC ₆ H ₅ (8 g.)	C ₆ H ₅ CH ₂ MgCl (6 equiv.)	CH ₃ (HCl·H ₂ N)CH(C ₆ H ₅)(C ₆ H ₅ CH ₂)COH (8.5 g.)	262

*Prepared by partial (*ca.* 65%) carbonation of the Grignard reagent mixture from (+)-*α*-pinene hydrochloride.

[†]For the pure enantiomorph, [α]_D 55.54°.

[‡]The mixture of products is attributed to a ketone isomerization equilibrium presumed to be established through a ketone-Grignard reagent coordination complex.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₂OCIN (<i>cont.</i>)			
CH ₃ CH(NH ₂ ·HCl)COC ₆ H ₅	4-CH ₃ C ₆ H ₄ MgBr	CH ₃ (H ₂ N)CH(C ₆ H ₅)(4-CH ₃ C ₆ H ₄)COH	263
CH ₃ CH(NH ₂ ·HCl)COC ₆ H ₅	4-CH ₃ OC ₆ H ₄ MgBr	CH ₃ (H ₂ N)CH(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)COH	263
CH ₃ CH(NH ₂ ·HCl)COC ₆ H ₅ (6.0 g.)	1-C ₁₀ H ₇ MgBr (35.5 g. C ₁₀ H ₇ Br)	CH ₃ (HCl·H ₂ N)CH(C ₆ H ₅)(1-C ₁₀ H ₇)COH (4.5 g.)	262
C₉H₁₂O₂ClN			
HCl·H ₂ NCH ₂ COC ₆ H ₄ -2-OCH ₃	C ₆ H ₅ MgBr	H ₂ NCH ₂ (C ₆ H ₅)(2-CH ₃ OC ₆ H ₄)COH	264
HCl·H ₂ NCH ₂ COC ₆ H ₄ -2-OCH ₃	4-CH ₃ OC ₆ H ₄ MgBr	H ₂ NCH ₂ (2-CH ₃ OC ₆ H ₄)(4-CH ₃ OC ₆ H ₄)COH	264
HCl·H ₂ NCH ₂ COC ₆ H ₄ -4-OCH ₃	C ₆ H ₅ MgBr	H ₂ NCH ₂ (C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)COH	264
C₉H₁₄O			
[(CH ₃) ₂ C=CH] ₂ CO	CH ₃ MgI	CH ₃ [(CH ₃) ₂ C=CH] ₂ COH (2.5%)	138
[(CH ₃) ₂ C=CH] ₂ CO	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ [(CH ₃) ₂ C=CH] ₂ COH	148
C₉H₁₄O₂			
HOCH=CHCO(CH ₂) ₂ CH=C(CH ₃) ₂	CH ₃ MgI	C ₁₀ H ₁₈ O ₂ (75%) [(CH ₃) ₂ C=CH(CH ₂) ₃ C(OH)(CH ₃)CH ₂ CHO] (?)	265
C₉H₁₄O₅			
CH ₃ COC(CH ₃)(CO ₂ CH ₃)CH ₂ CO ₂ CH ₃	<i>i</i> -C ₄ H ₉ MgBr	CH ₃ (<i>i</i> -C ₄ H ₉)[H ₃ CO ₂ CCH ₂ (CH ₃)-(H ₃ CO ₂ C)C]COH	266
CH ₃ COC(CH ₃)(CO ₂ CH ₃)CH ₂ CO ₂ CH ₃	C ₆ H ₅ MgBr	CH ₃ (C ₆ H ₅)[H ₃ CO ₂ CCH ₂ (CH ₃)(H ₃ CO ₂ C)C]COH	266
C₉H₁₆O			
<i>cis</i> - or <i>trans</i> -CH ₃ COC(<i>n</i> -C ₃ H ₇)=CHC ₂ H ₅ * (0.2 mole)	C ₂ H ₅ MgBr (7.2 g. Mg)	CH ₃ (C ₂ H ₅)[C ₂ H ₅ CH=C(<i>n</i> -C ₃ H ₇)]COH (14 g., crude); CH ₃ COCH(<i>n</i> -C ₃ H ₇)CH(C ₂ H ₅) ₂ (10 g.)	185
CH ₃ CO(CH ₂) ₂ C(<i>i</i> -C ₃ H ₇)=CH ₂	CH ₃ MgX	HO(CH ₃) ₂ C(CH ₂) ₂ C(<i>i</i> -C ₃ H ₇)=CH ₂ (80%)	267

*Colonge (185) regards as "*cis*" the isomer which forms the semicarbazone melting at 142°, and as "*trans*" the isomer that forms the semicarbazone melting at 122°.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₆O (<i>cont.</i>)			
CH ₃ CO(CH ₂) ₂ C(<i>i</i> -C ₃ H ₇)=CH ₂	(CH ₂) ₅ CHMgX	CH ₃ [(CH ₂) ₅ CH][H ₂ C=C(<i>i</i> -C ₃ H ₇)]COH (46.5%)	267
CH ₃ CO(CH ₂) ₂ C(<i>i</i> -C ₃ H ₇)=CH ₂	<i>n</i> -C ₆ H ₁₃ MgX	CH ₃ [H ₂ C=C(<i>i</i> -C ₃ H ₇)](<i>n</i> -C ₆ H ₁₃)COH (69%)	267
CH ₃ CO(CH ₂) ₂ C(<i>i</i> -C ₃ H ₇)=CH ₂	<i>i</i> -C ₄ H ₉ (<i>n</i> -C ₆ H ₁₃)CHMgBr	CH ₃ [H ₂ C=C(<i>i</i> -C ₃ H ₇)] [<i>i</i> -C ₄ H ₉ (<i>n</i> -C ₆ H ₁₃)CH]COH (45%)	267
<i>t</i> -C ₄ H ₉ CO(CH ₂) ₂ CH=CH ₂	CH ₃ MgI	CH ₃ [H ₂ C=CH(CH ₂) ₂](<i>t</i> -C ₄ H ₉)COH (90%)	134
C₉H₁₆O₂			
(CH ₃ CO) ₂ C(C ₂ H ₅) ₂	(≡CMgBr) ₂	CH ₃ CO(C ₂ H ₅) ₂ CC(CH ₃)(C≡CH)OH	85
C₉H₁₆O₃			
CH ₃ COC(C ₂ H ₅) ₂ CO ₂ CH ₃	CH ₃ MgI (1 equiv.)	(C ₂ H ₅) ₂ CHCOCO ₂ CH ₃ ; recovered ketone	152
CH ₃ COC(CH ₂) ₄ CO ₂ C ₂ H ₅ (21.5 g.)	C ₂ H ₅ MgI (23.4 g. C ₂ H ₅ I)	CH ₃ (C ₂ H ₅)[H ₅ C ₂ O ₂ (CH ₂) ₄]COH	269
CH ₃ CO(CH ₂) ₄ CO ₂ C ₂ H ₅ (33 g.)	<i>n</i> -C ₄ H ₉ MgBr (34 g. C ₄ H ₉ Br)	CH ₃ (<i>n</i> -C ₄ H ₉)[H ₅ C ₂ O ₂ (CH ₂) ₄]COH [yielding 25% <i>n</i> -C ₄ H ₉ CH(CH ₃)(CH ₂) ₄ CO ₂ H]	136
CH ₃ CO(CH ₂) ₄ CO ₂ C ₂ H ₅ (3.45 g.)	<i>n</i> -C ₁₈ H ₃₇ MgBr (8.65 g. C ₁₈ H ₃₇ Br)	CH ₃ [H ₅ C ₂ O ₂ (CH ₂) ₄](<i>n</i> -C ₁₈ H ₃₇)COH	269
C₉H₁₇ON			
CH ₃ CO(CH ₂) ₂ N(C ₂ H ₅) ₂	CH ₃ MgI	(C ₂ H ₅) ₂ N(CH ₂) ₂ C(CH ₃) ₂ OH	270
C₉H₁₈O			
CH ₃ CO- <i>n</i> -C ₇ H ₁₅	CH ₃ MgI	<i>n</i> -C ₇ H ₁₅ (CH ₃) ₂ COH (<i>ca.</i> quant)	268
CH ₃ COCH(<i>n</i> -C ₃ H ₇) ₂	(<i>n</i> -C ₃ H ₇) ₂ CHMgBr	CH ₃ CH(OH)CH(<i>n</i> -C ₃ H ₇) ₂ ; "other secondary products"	199
CH ₃ COC(C ₂ H ₅) ₃	CH ₃ MgBr	Addition (0%); enolization (94%)*	168
C ₂ H ₅ COCH(CH ₃)- <i>t</i> -C ₄ H ₉	CH ₃ MgCl	Addition (33%); enolization (62%)*	124

* "Grignard machine" study.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₈O (<i>cont.</i>)			
C ₂ H ₅ COC(C ₂ H ₅) ₃	C ₂ H ₅ MgBr (+ HCHO)*	(C ₂ H ₅) ₃ CCO(CH ₂) ₂ OH (34%)	192
<i>n</i> -C ₃ H ₇ COCH(CH ₃)- <i>n</i> -C ₃ H ₇	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₅ H ₁₁)[CH ₃ (<i>n</i> -C ₃ H ₇)CH]COH	11
(<i>n</i> -C ₄ H ₉) ₂ CO	(≡CMgBr) ₂	[≡CC(<i>n</i> -C ₄ H ₉) ₂ OH] ₂ (83%)	199
(<i>i</i> -C ₄ H ₉) ₂ CO	CH ₃ MgI	CH ₃ (<i>i</i> -C ₄ H ₉) ₂ COH	11
(<i>i</i> -C ₄ H ₉) ₂ CO	(≡CMgBr) ₂	[≡CC(<i>i</i> -C ₄ H ₉) ₂ OH] ₂ (80%)	21
<i>i</i> -C ₄ H ₉ CO- <i>t</i> -C ₄ H ₉	(≡CMgI) ₂	[≡CC(<i>i</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉)OH] ₂	125
(<i>t</i> -C ₄ H ₉) ₂ CO (21 g.)	H ₂ C=CHC≡CMgBr	H ₂ C=CHC≡C(<i>t</i> -C ₄ H ₉) ₂ COH (14 g.)	40
(<i>t</i> -C ₄ H ₉) ₂ CO	Butenyl-MgBr	CH ₃ CH=CHCH ₂ (<i>t</i> -C ₄ H ₉) ₂ COH (69%)	251
C₁₀H₆O₄			
Furil	CH ₃ MgI	2,3-Di- α -furyl-2,3-butadiene	271
Furil	C ₂ H ₅ MgI	3,4-Di- α -furyl-2,4-hexadiene	271
C₁₀H₇OCl₃			
C ₆ H ₅ COCH=CHCCl ₃	C ₆ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH(CCl ₃)C ₆ H ₅ (93%)	111
C₁₀H₈O₃			
HO ₂ CCH=CHCOC ₆ H ₅	C ₂ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH(C ₂ H ₅)CO ₂ H (?)	274
HO ₂ CCH=CHCOC ₆ H ₅ (11 g.)	C ₆ H ₅ MgBr (40 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)CO ₂ H (22.5%)	274
HO ₂ CCH=CHCOC ₆ H ₅	4-CH ₃ OC ₆ H ₄ MgBr	C ₆ H ₅ COCH ₂ CH(C ₆ H ₄ -4-OCH ₃)CO ₂ H (22%)	274
C₁₀H₉OBr			
CH ₃ COCBr=CHC ₆ H ₅ (28 g.)	C ₆ H ₅ MgBr (33 g. C ₆ H ₅ Br)	CH ₃ COCHBrCH(C ₆ H ₅) ₂ (35 g.)	272
C₁₀H₁₀O			
CH ₃ COCH=CHC ₆ H ₅ (15 g.)	CH ₃ MgI (32 g. CH ₃ I)	H ₂ C=C(CH ₃)CH=CHC ₆ H ₅	206
CH ₃ COCH=CHC ₆ H ₅ (60 g.)	C ₂ H ₅ MgI (18 g. Mg)	CH ₃ COCH ₂ CH(C ₂ H ₅)C ₆ H ₅ (41 g., 56.6%); diene (37.2%); condensate (6.3%)	111

*This reaction is in effect an enolate addition to formaldehyde.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₀H₁₀O (<i>cont.</i>)			
CH ₃ COCH=CHC ₆ H ₅	C ₂ H ₅ MgI	CH ₃ CH=C(CH ₃)CH=CHC ₆ H ₅ ("good yield")	206
CH ₃ COCH=CHC ₆ H ₅	H ₂ C=CHCH ₂ Br + Mg	CH ₃ (H ₂ C=CHCH ₂)(C ₆ H ₅ CH=CH)COH (31%)	599
CH ₃ COCH=CHC ₆ H ₅	C ₂ H ₅ OC≡CMgBr	CH ₃ (C ₂ H ₅ OC≡C)(C ₆ H ₅ CH=CH)COH (80%)	43
CH ₃ COCH=CHC ₆ H ₅ (35 g.)	<i>t</i> -C ₄ H ₉ MgCl (12 g. Mg)	CH ₃ COCH ₂ CH(<i>t</i> -C ₄ H ₉)C ₆ H ₅ (<i>ca.</i> 8 g., 15%); H ₂ C=C(<i>t</i> -C ₄ H ₉)CH=CHC ₆ H ₅ (27%)	276
CH ₃ COCH=CHC ₆ H ₅	<i>i</i> -C ₆ H ₁₁ MgBr	CH ₃ COCH ₂ CH(<i>i</i> -C ₆ H ₁₁)C ₆ H ₅ * (52%)	277
CH ₃ COCH=CHC ₆ H ₅ (240 g.)	C ₆ H ₅ MgI (72 g. Mg)	CH ₃ COCH ₂ CH(C ₆ H ₅) ₂ (18 g., 4.9%); diene	111
CH ₃ COCH=CHC ₆ H ₅ (36.4 g.)	(CH ₂) ₅ CHMgBr (<i>excess</i>)	CH ₃ COCH ₂ CH(C ₆ H ₅)CH(CH ₂) ₅ (37.2 g.); CH ₃ [(CH ₂) ₅ CH](C ₆ H ₅ CH=CH)COH	278
CH ₃ CH=CHCOC ₆ H ₅	CH ₃ MgI	<i>i</i> -C ₄ H ₉ COC ₆ H ₅ ; <i>no</i> carbinol.	256
CH ₃ CH=CHCOC ₆ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH(CH ₃)C ₆ H ₅ ; <i>no</i> carbinol	256
(CH ₂) ₂ CHCOC ₆ H ₅	C ₆ H ₅ MgBr	(CH ₂) ₅ CH(C ₆ H ₅) ₂ COH	279
C₁₀H₁₀O₂			
CH ₃ COCH=CHC ₆ H ₄ -2-OH (7.5 g.)	CH ₃ MgI (0.1 mole)	CH ₃ COCH ₂ CH(CH ₃)C ₆ H ₄ -2-OH (1.5 g.)	273
HOCH=C(CH ₃)COC ₆ H ₅ †	C ₂ H ₅ MgBr	HO(C ₂ H ₅)CHCH(CH ₃)COC ₆ H ₅	147
HOCH=C(CH ₃)COC ₆ H ₅ †	C ₆ H ₅ MgBr	C ₆ H ₅ CH=C(CH ₃)COC ₆ H ₅	147
C₁₀H₁₀O₃			
CH ₃ COCH ₂ O ₂ CC ₆ H ₅	C ₂ H ₅ MgBr (4 equiv.)	HO(CH ₃)(C ₂ H ₅)CCH ₂ OH; C ₆ H ₅ (C ₂ H ₅) ₂ COH; C ₆ H ₅ CO ₂ H	82
H ₃ CO ₂ CCOC ₆ H ₄ -4-CH ₃	C ₆ H ₅ MgBr	HO ₂ C(C ₆ H ₅)(4-CH ₃ C ₆ H ₄)COH	280
H ₅ C ₂ O ₂ CCOC ₆ H ₅	CH ₃ MgI (1 equiv.)	CH ₃ (H ₅ C ₂ O ₂ C)(C ₆ H ₅)COH (60%)	151, 187

*The abstract reports a "6-octanone," but this is obviously a misprint.

†The reactions reported could be more plausibly represented as those of C₆H₅COCH(CH₃)CHO or C₆H₅C(OH)=C(CH₃)CHO.

TABLE VI-XVIII (Continued)

Ketonic Comp'd	RMgX	Product(s)	Ref.
C₁₀H₁₀O₃ (cont.)			
H ₅ C ₂ O ₂ CCOC ₆ H ₅	C ₂ H ₅ MgBr (1 equiv.)	C ₂ H ₅ (H ₅ C ₂ O ₂ C)(C ₆ H ₅)COH (82%)	151, 187
H ₅ C ₂ O ₂ CCOC ₆ H ₅ (100 g.)	1-C ₁₀ H ₇ MgBr (137 g. C ₁₀ H ₇ Br)	HO ₂ C(C ₆ H ₅)(1-C ₁₀ H ₇)COH	280
C₁₀H₁₂O			
CH ₃ CO(CH ₂) ₂ C ₆ H ₅ (15 g.)	CH ₃ MgI (16 g. CH ₃ I)	C ₆ H ₅ CH ₂ CH ₂ (CH ₃) ₂ COH (10 g.)	146
CH ₃ CO(CH ₂) ₂ C ₆ H ₅ (15 g.)	C ₂ H ₅ MgI (16 g. C ₂ H ₅ I)	CH ₃ (C ₂ H ₅)(C ₆ H ₅ CH ₂ CH ₂)COH (13 g.)	146
CH ₃ CO(CH ₂) ₂ C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	CH ₃ (C ₆ H ₅ CH ₂)(C ₆ H ₅ CH ₂ CH ₂)COH	282
CH ₃ COC ₆ H ₃ -2,4-(CH ₃) ₂ *	H ₂ C=CHCH ₂ Br + Mg	CH ₃ (H ₂ C=CHCH ₂)[2,4-(CH ₃) ₂ C ₆ H ₃]COH (quant.)	283
CH ₃ COC ₆ H ₃ -2,4-(CH ₃) ₂	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ (<i>i</i> -C ₃ H ₇)[2,4-(CH ₃) ₂ C ₆ H ₃]COH (yielding 32% alkylated benzene on dehydr'n and hydrogen'n)	106
CH ₃ COC ₆ H ₃ -2,5-(CH ₃) ₂ *	H ₂ C=CHCH ₂ Br + Mg	CH ₃ (H ₂ C=CHCH ₂)[2,5-(CH ₃) ₂ C ₆ H ₃]COH (quant.)	283
CH ₃ COC ₆ H ₃ -3,4-(CH ₃) ₂ *	H ₂ C=CHCH ₂ Br + Mg	CH ₃ (H ₂ C=CHCH ₂)[3,4-(CH ₃) ₂ C ₆ H ₃]COH (96.4%)	283
C ₂ H ₅ COC ₆ H ₄ -4-CH ₃	H ₂ C=CHCH ₂ Br + Mg	C ₂ H ₅ (H ₂ C=CHCH ₂)(4-CH ₃ C ₆ H ₄)COH (75%)	284
<i>n</i> -C ₃ H ₇ COC ₆ H ₅	CH ₃ MgI	CH ₃ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅)COH (74%)	619
<i>n</i> -C ₃ H ₇ COC ₆ H ₅	C ₂ H ₅ MgBr	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅)COH	285
<i>n</i> -C ₃ H ₇ COC ₆ H ₅	C ₆ H ₅ MgBr	<i>n</i> -C ₃ H ₇ (C ₆ H ₅) ₂ COH	287
<i>n</i> -C ₃ H ₇ COC ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	<i>n</i> -C ₃ H ₇ (C ₆ H ₅)(C ₆ H ₅ CH ₂)COH (94%)	199
<i>n</i> -C ₃ H ₇ COC ₆ H ₅	<i>n</i> -C ₈ H ₁₇ MgBr	<i>n</i> -C ₃ H ₇ (C ₆ H ₅)(<i>n</i> -C ₈ H ₁₇)COH	144
<i>n</i> -C ₃ H ₇ COC ₆ H ₅	Isobornyl-MgCl [†]	<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CHOH, [α] _D 26.70° (50%) [†]	230

*Identification of the carbinols, and hence of the corresponding xylyl ketones, from *Beilstein*, 6 (296), 1931.

[†]Prepared by partial (ca. 65%) carbonation of the Grignard reagent mixture from (+)-α-pinene hydrochlorides.

[†]Activity of the pure enantiomorph, [α]_D 57.21°.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₂O (<i>cont.</i>)			
<i>n</i> -C ₃ H ₇ COC ₆ H ₅ (1.10 mole)	<i>n</i> -C ₁₆ H ₃₃ MgBr (1.25 mole)	<i>n</i> -C ₃ H ₇ (C ₆ H ₅)(<i>n</i> -C ₁₆ H ₃₃)COH (yielding 73% crude olefin)	231
<i>i</i> -C ₃ H ₇ COC ₆ H ₅ (30 g.)	C ₂ H ₅ MgI (48 g. C ₂ H ₅ I)	C ₂ H ₅ (<i>i</i> -C ₃ H ₇)(C ₆ H ₅)COH (28 g.)	286
<i>i</i> -C ₃ H ₇ COC ₆ H ₅	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇)(C ₆ H ₅)COH	286
<i>i</i> -C ₃ H ₇ COC ₆ H ₅	Isobornyl-MgCl*	<i>i</i> -C ₃ H ₇ (C ₆ H ₅)CHOH, [α] _D 26.40° (80%) [†]	230
C₁₀H₁₂O₂			
C ₂ H ₅ COC ₆ H ₄ -4-OCH ₃ (17 g.)	C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)CHMgCl (20 g. C ₁₀ H ₁₃ ClO)	C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)[C ₂ H ₅ (4-CH ₃ OC ₆ H ₄ CH]COH	288
C ₂ H ₅ COC ₆ H ₄ -4-OCH ₃ (17 g.)	C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)CHBr (23 g.) + Mg	C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)[C ₂ H ₅ (4-CH ₃ OC ₆ H ₄ CH]COH	288
C ₂ H ₅ COCH(OH)C ₆ H ₅	CH ₃ MgBr	HO(CH ₃)(C ₂ H ₅)CCH(OH)C ₆ H ₅ (80%)	289,258
C ₂ H ₅ COCH(OH)C ₆ H ₅	C ₂ H ₅ MgBr	HO(C ₂ H ₅) ₂ CCH(OH)C ₆ H ₅ (chiefly); HO(C ₂ H ₅)(C ₆ H ₅)CCH(OH)C ₂ H ₅	289,258
C ₂ H ₅ COCH(OH)C ₆ H ₅	<i>n</i> -C ₃ H ₇ MgBr	HO(C ₂ H ₅)(<i>n</i> -C ₃ H ₇)CCH(OH)C ₆ H ₅	289,258
C ₂ H ₅ CH(OH)COC ₆ H ₅	CH ₃ MgBr	HO(CH ₃)(C ₆ H ₅)CCH(OH)C ₂ H ₅ (84%)	289,258
C ₂ H ₅ CH(OH)COC ₆ H ₅	C ₂ H ₅ MgBr	β -HO(C ₂ H ₅)(C ₆ H ₅)CCH(OH)C ₂ H ₅	289,258
C ₂ H ₅ CH(OH)COC ₆ H ₅	<i>n</i> -C ₃ H ₇ MgBr	HO(<i>n</i> -C ₃ H ₇)(C ₆ H ₅)CCH(OH)C ₂ H ₅	289,258
C ₂ H ₅ CH(OH)COC ₆ H ₅	C ₆ H ₅ MgBr	HO(C ₆ H ₅) ₂ CCH(OH)C ₂ H ₅ (chiefly); HO(C ₂ H ₅)(C ₆ H ₅)CCH(OH)C ₆ H ₅	289,258
HO(CH ₃) ₂ CCOC ₆ H ₅	C ₆ H ₅ MgBr	HO(CH ₃) ₂ CC(C ₆ H ₅) ₂ OH	258,292
HO(CH ₃) ₂ CCOC ₆ H ₅	<i>t</i> -C ₄ H ₉ C \equiv CMgBr	HO(CH ₃) ₂ CC(C ₆ H ₅)(C \equiv C- <i>t</i> -C ₄ H ₉)OH (75.5%)	290
C₁₀H₁₂O₃			
CH ₃ COC ₆ H ₃ -2,5-(OCH ₃) ₂	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ (<i>i</i> -C ₃ H ₇)[2,5-(CH ₃ O) ₂ C ₆ H ₃]COH (90%)	281

*Prepared by partial (*ca.* 65%) carbonation of the Grignard reagent mixture from (+)- α -pinene hydrochlorides.

[†]Activity of the pure enantiomorph, [α]_D 47.66°.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₂O₃ (cont.)			
CH ₃ COCH(OH)C ₆ H ₄ -4-OCH ₃ (CH ₃ O) ₂ CHCOC ₆ H ₅ (9 g.)	C ₂ H ₅ MgBr (5 equiv.) C ₆ H ₅ MgBr (8 g. C ₆ H ₅ Br)	α -HO(CH ₃)(C ₂ H ₅)CCH(OH)C ₆ H ₄ -4-OCH ₃ (CH ₃ O) ₂ CH(C ₆ H ₅) ₂ COH (5 g., crude)	291 203
C₁₀H₁₃ON			
CH ₃ COC ₆ H ₄ -4-N(CH ₃) ₂ (14 g.)	C ₆ H ₅ (1-C ₁₀ H ₇)C=CHMgBr (32 g. C ₁₀ H ₁₃ Br)	CH ₃ [4-(CH ₃) ₂ NC ₆ H ₄][C ₆ H ₅ (1-C ₁₀ H ₇)C=CH]COH	180
CH ₃ CH(NHCH ₃)COC ₆ H ₅ (7 g.)	C ₆ H ₅ MgBr (7 g. C ₆ H ₅ Br)	CH ₃ (CH ₃ NH)CH(C ₆ H ₅) ₂ COH (5.8 g.)	293
C₁₀H₁₄OCIN			
CH ₃ CH(NH ₂ ·HCl)COC ₆ H ₄ -4-CH ₃ CH ₃ CH(NH ₂ ·HCl)COC ₆ H ₄ -4-CH ₃	C ₆ H ₅ MgBr 4-CH ₃ OC ₆ H ₄ MgBr	CH ₃ (H ₂ N)CH(C ₆ H ₅)(4-CH ₃ C ₆ H ₄)COH CH ₃ (H ₂ N)CH(4-CH ₃ C ₆ H ₄)(4-CH ₃ OC ₆ H ₄)COH	263 263
C₁₀H₁₄O₂CIN			
HCl·H ₂ NCH ₂ COC ₆ H ₄ -2-OC ₂ H ₅ HCl·H ₂ NCH ₂ COC ₆ H ₄ -4-OC ₂ H ₅ CH ₃ (HCl·H ₂ N)CHCOC ₆ H ₄ -4-OCH ₃ CH ₃ (HCl·H ₂ N)CHCOC ₆ H ₄ -4-OCH ₃	C ₆ H ₅ MgBr C ₆ H ₅ MgBr C ₆ H ₅ MgBr 4-CH ₃ C ₆ H ₄ MgBr	H ₂ NCH ₂ (C ₆ H ₅)(2-C ₂ H ₅ OC ₆ H ₄)COH H ₂ NCH ₂ (C ₆ H ₅)(4-C ₂ H ₅ OC ₆ H ₄)COH CH ₃ (H ₂ N)CH(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)COH CH ₃ (H ₂ N)CH(4-CH ₃ C ₆ H ₄)(4-CH ₃ OC ₆ H ₄)COH	264 264 263 263
C₁₀H₁₄O₃CIN			
HCl·H ₂ NCH ₂ COC ₆ H ₃ -2,4-(OCH ₃) ₂ HCl·H ₂ NCH ₂ COC ₆ H ₃ -2,5-(OCH ₃) ₂ HCl·H ₂ NCH ₂ COC ₆ H ₃ -3,4-(OCH ₃) ₂	C ₆ H ₅ MgBr C ₆ H ₅ MgBr C ₆ H ₅ MgBr	H ₂ NCH ₂ (C ₆ H ₅)[2,4-(CH ₃ O) ₂ C ₆ H ₃]COH H ₂ NCH ₂ (C ₆ H ₅)[2,5-(CH ₃ O) ₂ C ₆ H ₃]COH H ₂ NCH ₂ (C ₆ H ₅)[3,4-(CH ₃ O) ₂ C ₆ H ₃]COH	264 264 264
C₁₀H₁₆O₅			
CH ₃ COCH(CO ₂ C ₂ H ₅)CH ₂ CO ₂ C ₂ H ₅	CH ₃ MgI (1 equiv.)	Enolization, chiefly; traces ethyl terebinat	151,187
C₁₀H₁₇ON			
CH ₃ COC(CH ₃)=CHN(CH ₂) ₅	C ₂ H ₅ MgBr	CH ₃ COC(CH ₃)=CHC ₂ H ₅	153

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₀H₁₈O			
CH ₃ COCH=CH- <i>n</i> -C ₆ H ₁₃	CH ₃ MgI	H ₂ C=C(CH ₃)CH=CH- <i>n</i> -C ₆ H ₁₃ (16%)	294
CH ₃ COCH=CH- <i>n</i> -C ₆ H ₁₃	C ₂ H ₅ MgBr	CH ₃ CH=C(CH ₃)CH=CH- <i>n</i> -C ₆ H ₁₃ ; H ₂ C=C(C ₂ H ₅)CH=CH- <i>n</i> -C ₆ H ₁₃	294
CH ₃ COCH=CH- <i>n</i> -C ₆ H ₁₃	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₄ H ₉ CH=C(CH ₃)CH=CH- <i>n</i> -C ₆ H ₁₃ ; H ₂ C=C(<i>i</i> -C ₅ H ₁₁)CH=CH- <i>n</i> -C ₆ H ₁₃	294
H ₂ C=CHCOC(C ₂ H ₅) ₃	CH ₃ MgBr	Addition (58%); enolization (0%)*	168
C₁₀H₁₈O₃			
CH ₃ COCH(O ₂ CCH ₃)- <i>n</i> -C ₅ H ₁₁ (12.7 g.)	CH ₃ MgBr (15 g. Mg)	<i>t</i> -C ₄ H ₉ OH ("a little"); HO(CH ₃) ₂ CCH(OH)- <i>n</i> -C ₅ H ₁₁ (6.5 g.)	295
CH ₃ COC(C ₂ H ₅) ₂ CO ₂ CH ₃ (40 g.)	CH ₃ MgI (1 equiv.)	(C ₂ H ₅) ₂ CHCO ₂ C ₂ H ₅ (10 g.); recovered ketone (20 g.) [†]	151
CH ₃ COC(C ₂ H ₅) ₂ CO ₂ CH ₃	CH ₃ MgI (3 equiv.)	Recovered ketone (<i>ca.</i> quant.) [†]	151
CH ₃ COC(C ₂ H ₅) ₂ CO ₂ CH ₃ (30 g.)	CH ₃ MgI (3 equiv.)	C ₈ H ₁₆ , b.p. 115–120° (10 g.); <i>t</i> -C ₄ H ₉ OH (?) [§]	151
C₁₀H₁₉ON			
<i>n</i> -C ₃ H ₇ COCH=CHN(C ₂ H ₅) ₂	C ₂ H ₅ MgBr (1.5 equiv.)	<i>n</i> -C ₃ H ₇ COCH=CHC ₂ H ₅	153
C₁₀H₁₉O₂N			
C ₂ H ₅ CO(CH ₂) ₂ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr (excess)	HO(C ₂ H ₅) ₂ C(CH ₂) ₂ CON(C ₂ H ₅) ₂ (chiefly); (C ₂ H ₅ COCH ₂ —) ₂ (5%); 2,2,5-triethyldihydrofuran	296

* "Grignard machine" study.

[†] Dropwise addition of Grignard reagent solution to ketone; twenty-four hours at room temperature.[‡] Gradual addition of ketone to Grignard reagent solution; three days reflux.[§] Gradual addition of ketone to Grignard solution; 8 hours at 100° (autoclave).

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₂₀O			
C ₂ H ₅ COCH(CH ₃)- <i>n</i> -C ₅ H ₁₁	<i>n</i> -C ₅ H ₁₁ MgBr (1.2 equiv.)	C ₂ H ₅ (<i>n</i> -C ₅ H ₁₁)[CH ₃ (<i>n</i> -C ₅ H ₁₁)CH]COH	297
<i>n</i> -C ₃ H ₇ CO- <i>n</i> -C ₆ H ₁₃	H ₂ C=CHCH ₂ MgCl	H ₂ C=CHCH ₂ (<i>n</i> -C ₃ H ₇)(<i>n</i> -C ₆ H ₁₃)COH	298
<i>n</i> -C ₃ H ₇ CO- <i>n</i> -C ₆ H ₁₃ (11 g.)	<i>n</i> -C ₅ H ₁₁ MgBr (22 g. C ₅ H ₁₁ Br)	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₅ H ₁₁)(<i>n</i> -C ₆ H ₁₃)COH	297, 11
<i>n</i> -C ₃ H ₇ COCH ₂ CH(CH ₃)- <i>n</i> -C ₃ H ₇	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₅ H ₁₁)[CH ₃ (<i>n</i> -C ₃ H ₇)CHCH ₂]COH (yielding olefin <i>ca.</i> quant.)	297
<i>t</i> -C ₄ H ₉ COCH ₂ - <i>t</i> -C ₄ H ₉	CH ₃ MgI	CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)COH (51%)	299
<i>t</i> -C ₄ H ₉ COCH(C ₂ H ₅) ₂	CH ₃ MgCl	Addition (19%); enolization (5%)*	124
<i>t</i> -C ₄ H ₉ COCH(C ₂ H ₅) ₂ (0.5 mole)	<i>t</i> -C ₄ H ₉ MgCl (0.8 mole)	<i>t</i> -C ₄ H ₉ [(C ₂ H ₅) ₂ CH]CHOH (38%); recovered ketone (45%)	305
C₁₁H₈OS			
2-Benzoylthiophene	C ₆ H ₅ MgBr	α-C ₄ H ₃ S(C ₆ H ₅) ₂ COH	272
2-Benzoylthiophene	1-C ₁₀ H ₇ CH ₂ MgCl	α-C ₄ H ₃ S(C ₆ H ₅)C≡CH-1-C ₁₀ H ₇	301
C₁₁H₉ON			
1-Acetylisquinoline (1.71 g.)	CH ₃ MgI (4.26 g. CH ₃ I)	2-(1-Isoquinolyl)-2-propanol (1.05 g., 56%)	302
1-Acetylisquinoline (0.01 mole)	C ₆ H ₅ MgBr (0.03 mole)	1-Phenyl-1-(1-isoquinolyl)ethanol (1.92 g., 47%)	302
4-Acetylisquinoline (0.0025 mole)	CH ₃ MgI (0.0075 mole)	2-(4-Isoquinolyl)-2-propanol (0.35 g., 75%)	302
4-Acetylisquinoline (0.01 mole)	C ₆ H ₅ MgBr (0.03 mole)	1-Phenyl-1-(4-isoquinolyl)ethanol (1.74 g., 70%)	302
C₁₁H₁₀O			
C ₂ H ₅ COC≡CC ₆ H ₅ (10.7 g.)	CH ₃ MgI (10.6 g. CH ₃ I)	CH ₃ CH=C(CH ₃)C≡CC ₆ H ₅	300

* "Grignard machine" study.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₁OS₂			
2,5-Dimethyl-3-(2-thenoyl)thiophene (5 g.)	C ₆ H ₅ CH ₂ MgCl (5 g. C ₇ H ₇ Cl)	Carbinol (yielding 5 g. dehydrate)	254
C₁₁H₁₀O₃			
HO ₂ CCH=CHCOC ₆ H ₄ -4-CH ₃	C ₆ H ₅ MgBr	4-CH ₃ C ₆ H ₄ COCH ₂ CH(C ₆ H ₅)CO ₂ H (27.2%)	274
C₁₁H₁₁ON			
2-Methyl-3-acetylpyrrocoline (1 mole)	C ₂ H ₅ MgBr (2.5 mole)	3-Methylpyrrocoline (5.8 g.); C ₁₃ H ₁₅ N (22.6 g.); C ₁₅ H ₂₁ N (26.6 g.)	306,304; cf. 318
C₁₁H₁₂O			
C ₂ H ₅ COCH=CHC ₆ H ₅	C ₂ H ₅ MgBr	C ₂ H ₅ COCH ₂ CH(C ₂ H ₅)C ₆ H ₅ (71%); HO(C ₂ H ₅) ₂ CCH=CHC ₆ H ₅	111
C ₂ H ₅ COCH=CHC ₆ H ₅ (30.0 g.)	<i>i</i> -C ₄ H ₉ MgBr	C ₂ H ₅ COCH ₂ CH(<i>i</i> -C ₄ H ₉)C ₆ H ₅ (23.5 g.); HO(C ₂ H ₅)(<i>i</i> -C ₄ H ₉)CCH=CHC ₆ H ₅	111
C ₂ H ₅ COCH=CHC ₆ H ₅ (100 g.)	C ₆ H ₅ MgBr	C ₂ H ₅ COCH ₂ CH(C ₆ H ₅) ₂ (60 g., 40%); HO(C ₂ H ₅)(C ₆ H ₅)CCH=CHC ₆ H ₅	111
C ₂ H ₅ COCH=CHC ₆ H ₅ (40 g.)	(CH ₂) ₅ CHMgBr	C ₂ H ₅ COCH ₂ CH(C ₆ H ₅)CH(CH ₂) ₅ (43 g.); C ₂ H ₅ [(CH ₂) ₅ CH](C ₆ H ₅ CH=CH)COH	278
C ₆ H ₅ COCH=C(CH ₃) ₂	C ₆ H ₅ MgBr	C ₆ H ₅ COCH ₂ C(CH ₃) ₂ C ₆ H ₅ ; no carbinol	256
2,4,6-(CH ₃) ₃ C ₆ H ₂ CH=CO	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	312
C₁₁H₁₂O₂			
CH ₃ COC ₆ H ₄ -4-OCH ₂ CH=CH ₂ (17.6 g.)	C ₆ H ₅ MgBr (40 g. C ₆ H ₅ Br)	H ₂ C=C(C ₆ H ₅)C ₆ H ₄ -4-OH (13.5 g., 70%)	307
CH ₃ COCH=CHC ₆ H ₄ -4-OCH ₃ (60 g.)	C ₂ H ₅ MgBr	CH ₃ COCH ₂ CH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ (43 g.)	111

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₂O₂ (cont.)			
CH ₃ COCH=CHC ₆ H ₄ -4-OCH ₃	(CH ₂) ₅ CHMgBr (excess)	CH ₃ COCH ₂ CH[CH(CH ₂) ₅]C ₆ H ₄ -4-OCH ₃ (44 g.); CH ₃ [(CH ₂) ₅ CH](4-CH ₃ OC ₆ H ₄ CH=CH)COH	278
C₁₁H₁₂O₃			
CH ₃ COCH(O ₂ CCH ₃)C ₆ H ₅ + C ₆ H ₅ COCH(O ₂ CCH ₃)CH ₃	CH ₃ MgBr	HO(CH ₃) ₂ CCH(OH)C ₆ H ₅ ; HO(CH ₃)(C ₆ H ₅)CCH(OH)CH ₃	313
C ₆ H ₅ COCH(O ₂ CCH ₃)CH ₃	CH ₃ MgBr	HO(CH ₃)(C ₆ H ₅)CCH(OH)CH ₃	313
C ₆ H ₅ CO(CH ₂) ₂ CO ₂ CH ₃	CH ₃ MgI	HO(CH ₃)(C ₆ H ₅)C(CH ₂) ₂ C(CH ₃) ₂ OH (88%)	314
C ₆ H ₅ CO(CH ₂) ₂ CO ₂ CH ₃	C ₆ H ₅ MgBr	[HO(C ₆ H ₅) ₂ CCH ₂ —] ₂	314
2,6-(CH ₃ CO) ₂ -4-CH ₃ C ₆ H ₂ OH (19.2 g.)	CH ₃ MgI (170.4 g. CH ₃ I)	2,6-Bis-(2-hydroxy-2-propyl)-4-methylphenol (14 g., 51%)	303
C₁₁H₁₂O₄			
1-Acetyl-1-carbethoxy-2- α -furyl ethene (25 g.)	C ₂ H ₅ MgI (45 g. C ₂ H ₅ I)	CH ₃ COCH(CO ₂ C ₂ H ₅)CH(C ₂ H ₅)- α -C ₄ H ₃ O (17 g.)	308
1-Acetyl-2-carbethoxy-2- α -furyl ethene (25 g.)	<i>n</i> -C ₃ H ₇ MgBr (36 g. C ₃ H ₇ Br)	CH ₃ COCH(CO ₂ C ₂ H ₅)CH(<i>n</i> -C ₃ H ₇)- α -C ₄ H ₃ O (16 g., 55%)	308
1-Acetyl-2-carbethoxy-2- α -furyl ethene (20 g.)	C ₆ H ₅ MgBr (42 g. C ₆ H ₅ Br)	CH ₃ COCH(CO ₂ C ₂ H ₅)CH(α -C ₄ H ₃ O)C ₆ H ₅ (15 g., 52%)	308
1-Carbethoxy-1- α -furoylcyclopropane	C ₆ H ₅ MgBr	α -(2-Furyl)- α -(1-carbethoxy-1-cyclopropyl)benzyl alcohol	319
C₁₁H₁₃ON			
(CH ₃) ₂ NCH=CHCOC ₆ H ₅	C ₂ H ₅ MgBr (1.5 equiv.)	C ₂ H ₅ CH=CHCOC ₆ H ₅	153
(CH ₃) ₂ NCH=CHCOC ₆ H ₅	C ₆ H ₅ MgBr (1.5 equiv.)	C ₆ H ₅ COCH=CHC ₆ H ₅	153

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₁H₁₃O₂Cl			
CH ₃ COC ₆ H-2,4-(CH ₃) ₂ -3-Cl-6-OCH ₃	C ₂ H ₅ MgBr (+ CO ₂)	2,4-(CH ₃) ₂ -3-Cl-6-CH ₃ OC ₆ HCOCH ₂ CO ₂ H (45%)	315
C₁₁H₁₃O₂N			
CH ₃ COC(=NOCH ₂ C ₆ H ₅)CH ₃	CH ₃ MgI	HO(CH ₃) ₂ CC(=NOCH ₂ C ₆ H ₅)CH ₃ (75%)	90
C₁₁H₁₄O			
CH ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	CH ₃ MgI (2 equiv.)	Recovered ketone	206
CH ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (49.0 g., 0.3 mole)	Butenyl-MgBr (0.36 mole)	CH ₃ [CH ₃ (H ₂ C=CH)CH][2,4,6- (CH ₃) ₃ C ₆ H ₂]COH (83%); recovered ketone (12%); butenes (<3%)	309,316
CH ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (8.0 g., 0.05 mole)	C ₆ H ₅ CH ₂ MgCl (9.5 g., 0.075 mole C ₇ H ₇ Cl)	CH ₃ (C ₆ H ₅ CH ₂)[2,4,6-(CH ₃) ₃ C ₆ H ₂]COH (52%); "enolization products" (38%)	309,316
C ₂ H ₅ COC ₆ H ₃ -2,4-(CH ₃) ₂	C ₂ H ₅ MgBr	2,4-(CH ₃) ₂ C ₆ H ₃ (C ₂ H ₅) ₂ COH (yielding 56.5% alkylated benzene on dehydr'n and hydrogen'n)	106
<i>n</i> -C ₃ H ₇ COC ₆ H ₄ -4-CH ₃	H ₂ C=CHCH ₂ Br + Mg	H ₂ C=CHCH ₂ (<i>n</i> -C ₃ H ₇)(4-CH ₃ C ₆ H ₄)COH (75%)	284
<i>n</i> -C ₄ H ₉ COC ₆ H ₅	Isobornyl-MgCl*	<i>n</i> -C ₄ H ₉ (C ₆ H ₅)CHOH, [α] _D 21.10° (44%) [†]	230
<i>s</i> -C ₄ H ₉ COC ₆ H ₅	Isobornyl-MgCl	<i>s</i> -C ₄ H ₉ (C ₆ H ₅)CHOH, [α] _D 25.9° (90%) [‡]	230
<i>t</i> -C ₄ H ₉ COC ₆ H ₃ (60 g.)	CH ₃ MgI	CH ₃ (<i>t</i> -C ₄ H ₉)(C ₆ H ₅)COH (54 g., 84%)	234,320
<i>t</i> -C ₄ H ₉ COC ₆ H ₅ (70 g.)	C ₂ H ₅ MgI	C ₂ H ₅ (<i>t</i> -C ₄ H ₉)(C ₆ H ₅)COH (51 g., 85%)	234,321
<i>t</i> -C ₄ H ₉ COC ₆ H ₅	<i>n</i> -C ₃ H ₇ MgI	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)CHOH	234,320
<i>t</i> -C ₄ H ₉ COC ₆ H ₅	<i>i</i> -C ₃ H ₇ MgI	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)CHOH	234
<i>t</i> -C ₄ H ₉ COC ₆ H ₅	C ₆ H ₅ MgBr	<i>t</i> -C ₄ H ₉ (C ₆ H ₅) ₂ COH (70%); CH ₃ COC ₆ H ₅ ; (C ₆ H ₅) ₂ CO	234,320

*Prepared by partial (ca. 65%) carbonation of the Grignard reagent mixture from (+)-α-pinene hydrochloride.

[†]Activity of pure enantiomorph, [α]_D 40.83°.

[‡]Activity of pure enantiomorph, [α]_D 36.0°.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₄O (<i>cont.</i>)			
<i>t</i> -C ₄ H ₉ COC ₆ H ₅ (162 g.)	<i>t</i> -C ₄ H ₉ C≡CMgBr (82 g. C ₆ H ₁₀)	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)(<i>t</i> -C ₄ H ₉ C≡C)COH (200 g., 68%)	656
<i>t</i> -C ₄ H ₉ COC ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)(C ₆ H ₅ CH ₂)COH (75%); (C ₆ H ₅ CH ₂ —) ₂	234, 230
<i>t</i> -C ₄ H ₉ COC ₆ H ₅	4-CH ₃ OC ₆ H ₄ MgBr	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)COH	234
<i>t</i> -C ₄ H ₉ COC ₆ H ₅ (5.3 g.)	C ₆ H ₅ C≡CMgBr (6 g. C ₆ H ₅ C≡CH)	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)(C ₆ H ₅ C≡C)COH (8.8 g., 98%)	310
<i>t</i> -C ₄ H ₉ COC ₆ H ₅	4-C ₂ H ₅ C ₆ H ₄ MgBr	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)(4-C ₂ H ₅ C ₆ H ₄)COH	234
C₁₁H₁₄ON₂			
CH ₃ COC[=NN(CH ₃)C ₆ H ₅]CH ₃	CH ₃ MgI	HO(CH ₃) ₂ CC[=NN(CH ₃)C ₆ H ₅]CH ₃ (75–80%)	657
CH ₃ COC[=NN(CH ₃)C ₆ H ₅]CH ₃	C ₂ H ₅ MgI	HO(CH ₃)(C ₂ H ₅)CC[=NN(CH ₃)C ₆ H ₅]CH ₃ (65%)	657
CH ₃ COC[=NN(CH ₃)C ₆ H ₅]CH ₃	C ₆ H ₅ MgBr	HO(CH ₃)(C ₆ H ₅)CC[=NN(CH ₃)C ₆ H ₅]CH ₃ (76%)	657
C₁₁H₁₄O₂			
C ₂ H ₅ O(CH ₂) ₂ COC ₆ H ₅ (33 g.)	C ₂ H ₅ MgBr	C ₂ H ₅ (C ₂ H ₅ OCH ₂ CH ₂)(C ₆ H ₅)COH (22 g.)	147
C ₂ H ₅ O(CH ₂) ₂ COC ₆ H ₅ (32 g.)	C ₆ H ₅ MgBr	C ₂ H ₅ OCH ₂ CH ₂ (C ₆ H ₅) ₂ COH (30 g.)	147
HO(CH ₃) ₂ CCOC ₆ H ₄ -4-CH ₃ (18 g.)	C ₆ H ₅ C≡CMgBr (31.2 g. C ₆ H ₅ C≡CH)	HO(CH ₃) ₂ CC(C ₆ H ₄ -4-CH ₃)(C≡CC ₆ H ₅)OH (75%)	311
C₁₁H₁₄O₃			
CH ₃ COC ₆ H ₂ -2,5-(OH) ₂ -4- <i>n</i> -C ₃ H ₇	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ (<i>i</i> -C ₃ H ₇)[2,5-(HO) ₂ -4- <i>n</i> -C ₃ H ₇ C ₆ H ₂]COH (84%)	281
C ₂ H ₅ COCH(OH)C ₆ H ₄ -4-OCH ₃	CH ₃ MgI (5 equiv.)	β-HO(CH ₃)(C ₂ H ₅)CCH(OH)C ₆ H ₄ -4-OCH ₃	291
C ₂ H ₅ COCH(OH)C ₆ H ₄ -4-OCH ₃	<i>n</i> -C ₃ H ₇ MgBr (5 equiv.)	α-HO(C ₂ H ₅)(<i>n</i> -C ₃ H ₇)CCH(OH)C ₆ H ₄ -4-OCH ₃	291
C ₂ H ₅ COCH(OH)C ₆ H ₄ -4-OCH ₃	C ₆ H ₅ MgBr	α-HO(C ₂ H ₅)(C ₆ H ₅)CCH(OH)C ₆ H ₄ -4-OCH ₃	322
C ₂ H ₅ COCH(OH)C ₆ H ₄ -4-OCH ₃	4-CH ₃ OC ₆ H ₄ MgBr	α-HO(C ₂ H ₅)(4-CH ₃ OC ₆ H ₄)CCH(OH)C ₆ H ₄ -4-OCH ₃	322

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₄O₄			
Ethyl furoyldimethylacetate	C ₂ H ₅ MgBr	HO(C ₂ H ₅)(α -C ₄ H ₈ O)CC(CH ₃) ₂ CO ₂ C ₂ H ₅ ("small yield")	319
Ethyl furoyldimethylacetate	C ₆ H ₅ MgBr	(α -C ₄ H ₃ O)CO[(C ₆ H ₅) ₂ CH]C(CH ₃) ₂	319
C₁₁H₂₂O			
CH ₃ CO- <i>n</i> -C ₉ H ₁₉	CH ₃ MgI	<i>n</i> -C ₉ H ₁₉ (CH ₃) ₂ COH (<i>ca.</i> quant.)	268
CH ₃ CO- <i>n</i> -C ₉ H ₁₉	(\equiv CMgBr) ₂	[\equiv CC(CH ₃)(<i>n</i> -C ₉ H ₁₉)OH] ₂ (71%)	323
CH ₃ CO- <i>n</i> -C ₉ H ₁₉ (170 g.)	<i>n</i> -C ₅ H ₁₁ MgBr (1 equiv.)	CH ₃ (<i>n</i> -C ₅ H ₁₁)(<i>n</i> -C ₉ H ₁₉)COH (80 ml.); re- covered ketone (50 ml.); C ₁₀ H ₂₂ (20 ml.)	100
CH ₃ COCH(<i>t</i> -C ₄ H ₉) ₂	<i>i</i> -C ₃ H ₇ MgX	Recovered ketone (85-90%)*	324
CH ₃ COCH(<i>t</i> -C ₄ H ₉) ₂	<i>i</i> -C ₄ H ₉ MgX	Recovered ketone (85-90%)*	324
CH ₃ COCH(<i>t</i> -C ₄ H ₉) ₂	<i>t</i> -C ₄ H ₉ MgX	Recovered ketone (85-90%)*	324
C₁₂H₉ON			
4-Benzoylpyridine	C ₆ H ₅ MgBr	γ -C ₅ H ₅ N(C ₆ H ₅) ₂ COH	325, 326
C₁₂H₁₀O			
CH ₃ CO-1-C ₁₀ H ₇	CH ₃ MgI	1-C ₁₀ H ₇ (CH ₃) ₂ COH (<i>ca.</i> quant.)	18, 334
CH ₃ CO-1-C ₁₀ H ₇ (42.5 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (63.7 g. C ₉ H ₁₁ Br)	1-C ₁₀ H ₇ [2,4,6-(CH ₃) ₃ CH ₂]C \equiv CH ₂ (8.2 g.); recovered ketone (26 g., 61%); 1,3,5- (CH ₃) ₃ C ₆ H ₃ (20 g.)	327
CH ₃ CO-2-C ₁₀ H ₇	CH ₃ MgI	2-C ₁₀ H ₇ (CH ₃) ₂ COH (yielding 85% olefin)	328, 330
CH ₃ CO-2-C ₁₀ H ₇	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)(2-C ₁₀ H ₇)COH + CH ₃ (2-C ₁₀ H ₇)C \equiv CHCH ₃ (yielding a total of 77% olefin)	328
CH ₃ CO-2-C ₁₀ H ₇	2-CH ₃ C ₆ H ₄ MgBr (95 g. C ₇ H ₇ Br)	CH ₃ (2-CH ₃ C ₆ H ₄)(2-C ₁₀ H ₇)COH (yielding 83 g., 68% olefin)	331

*Attributed to substantially complete enolization.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₂H₁₀OS			
2-Phenylacetylthiophene	C ₂ H ₅ MgBr (+ NaNH ₂)	2-(Ethylphenylacetyl)thiophene	301
2-Phenylacetylthiophene	C ₂ H ₅ MgBr (excess) (+ NaNH ₂)	After dehydr'n: 1,2-diethyl-1-(2-thienyl)-2-phenylethene	301
C₁₂H₁₂O			
CH ₃ COCH=CHCH=CHC ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH=C(CH ₃)CH=CHCH=CHC ₆ H ₅ ("poor yield")	329
<i>n</i> -C ₃ H ₇ COC≡CC ₆ H ₅ (18 g.)	C ₂ H ₅ MgBr (13 g. C ₂ H ₅ Br)	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅ C≡C)COH	300
C₁₂H₁₂OCIN			
HCl·H ₂ NCH ₂ CO-1-C ₁₀ H ₇ (12.8 g.)	1-C ₁₀ H ₇ MgBr* (8.5 g. Mg)	HCl·H ₂ NCH ₂ (1-C ₁₀ H ₇) ₂ COH (9.5 g.)	337
C₁₂H₁₂O₃			
HO ₂ C(CH ₃)C=C(CH ₃)COC ₆ H ₅ (5 g.)	C ₆ H ₅ MgBr (8.5 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH(CH ₃)C(CH ₃)(C ₆ H ₅)CO ₂ H (2 form's, aggregating 5.9 g., 85.5%)	332
C₁₂H₁₄O			
<i>i</i> -C ₃ H ₇ COCH=CHC ₆ H ₅ (60 g.)	C ₂ H ₅ MgBr	<i>i</i> -C ₃ H ₇ COCH ₂ CH(C ₂ H ₅)C ₆ H ₅ (32 g.)	111
<i>i</i> -C ₃ H ₇ COCH=CHC ₆ H ₅ (30 g.)	C ₆ H ₅ MgBr	<i>i</i> -C ₃ H ₇ COCH ₂ CH(C ₆ H ₅) ₂ (37.5 g.); HO(C ₂ H ₅)(<i>i</i> -C ₃ H ₇)CCH=CHC ₆ H ₅ (<i>ca.</i> 4 g.)	111
C ₂ H ₅ CH=C(CH ₃)COC ₆ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ COCH(CH ₃)CH(C ₂ H ₅)C ₆ H ₅	147
C₁₂H₁₄O₃			
CH ₃ COCH(O ₂ CCH ₃)C ₆ H ₄ -4-ClI ₃ (17 g.)	CH ₃ MgBr (6 g. Mg)	HO(CH ₃) ₂ CCH(OH)C ₆ H ₄ -4-CH ₃ (3.6 g.); <i>t</i> -C ₄ H ₉ OH	14
CH ₃ COCH(O ₂ CC ₆ H ₅)C ₂ H ₅	CH ₃ MgBr	HO(CH ₃) ₂ CCH(OH)C ₆ H ₅	258

*It is reported that the Grignard reagent was prepared from "β-bromonaphthalene," but this is apparently a misprint.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₂H₁₄O₃ (cont.)			
CH ₃ COC(CH ₃)(CH ₂ CO ₂ H)C ₆ H ₅	CH ₃ MgI	HO(CH ₃) ₂ CC(CH ₃)(CH ₂ CO ₂ H)C ₆ H ₅	336
CH ₃ COC(CH ₃)(CH ₂ CO ₂ H)C ₆ H ₅	CH ₃ MgI	β,γ-Dimethyl-β-phenyl-γ-hydroxyvaleric acid γ-lactone	335
HO ₂ CCH(CH ₃)CH ₂ COC ₆ H ₄ -4-CH ₃	CH ₃ MgI	CH ₃ (4-CH ₃ C ₆ H ₄)C=CHCH(CH ₃)CO ₂ H	317
C₁₂H₁₅O₂Cl			
CH ₃ COC ₆ H-2,4-(CH ₃) ₂ -3-Cl-6-OC ₂ H ₅	C ₂ H ₅ MgBr (+ CO ₂)	2,4-(CH ₃) ₂ -3-Cl-6-C ₂ H ₅ OC ₆ HCOCH ₂ CO ₂ H (55%)	315
C ₂ H ₅ COC ₆ H-2,4-(CH ₃) ₂ -3-Cl-6-OCH ₃	C ₂ H ₅ MgBr (+ CO ₂)	2,4-(CH ₃) ₂ -3-Cl-6-CH ₃ OCHCH(CH ₃)CO ₂ H (50%)	315
C₁₂H₁₆O			
CH ₃ COCH ₂ C(CH ₃) ₂ C ₆ H ₅	CH ₃ MgI	HO(CH ₃) ₂ CCH ₂ C(CH ₃) ₂ C ₆ H ₅	68
CH ₃ COCH ₂ C(CH ₃) ₂ C ₆ H ₅ (19.4 g.)	C ₆ H ₅ MgBr (25.3 ml. C ₂ H ₅ Br)	CH ₃ (C ₆ H ₅)C=CHC(CH ₃) ₂ C ₆ H ₅ (8 g.)	57
CH ₃ COC ₆ H ₄ -4- <i>t</i> -C ₄ H ₉	CH ₃ MgI (2.5 equiv.)	4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ (CH ₃) ₂ COH (75-80%)	338
<i>n</i> -C ₃ H ₇ COC ₆ H ₃ -2,4-(CH ₃) ₂	CH ₃ MgI	CH ₃ (<i>n</i> -C ₃ H ₇)[2,4-(CH ₃) ₂ C ₆ H ₃]COH (yielding 72% alkylated benzene upon dehydr'n and hydrogen'n)	106
<i>i</i> -C ₃ H ₇ COC ₆ H ₃ -2,4-(CH ₃) ₂	CH ₃ MgI	CH ₃ (<i>i</i> -C ₃ H ₇)[2,4-(CH ₃) ₂ C ₆ H ₃]COH (yielding 64% alkylated benzene upon dehydr'n and hydrogen'n)	106
C₁₂H₁₆O₂			
C ₂ H ₅ COC ₆ H ₂ -2,4-(CH ₃) ₂ -6-OCH ₃	C ₂ H ₅ MgBr (+ CO ₂)	2,4-(CH ₃) ₂ -6-CH ₃ OC ₆ H ₂ CH(CH ₃)CO ₂ H (30%); unidentified products	315
C₁₂H₁₆O₃			
<i>n</i> -C ₃ H ₇ COC ₆ H ₃ -3,5-(OCH ₃) ₂ (21.2 g.)	CH ₃ MgI (14.5 g. CH ₃ I)	CH ₃ (<i>n</i> -C ₃ H ₇)[3,5-(CH ₃ O) ₂ C ₆ H ₃]COH	333
<i>n</i> -C ₃ H ₇ COCH(OH)C ₆ H ₄ -4-OCH ₃	C ₂ H ₅ MgBr (5 equiv.)	β-HO(C ₂ H ₅)(<i>n</i> -C ₃ H ₇)CCH(OH)C ₆ H ₄ -4-OCH ₃	291

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₁₈O			
8-Acetylcamphene	C ₆ H ₅ MgBr	8-(α -Phenylvinyl)camphene	339
C₁₂H₂₂O			
CH ₃ CO(CH ₂) ₈ CH=CH ₂ (15 g.)	CH ₃ (<i>n</i> -C ₇ H ₁₅)CH(CH ₂) ₂ MgBr	CH ₃ [H ₂ C=CH(CH ₂) ₈][CH ₃ (<i>n</i> -C ₇ H ₁₅)CH(CH ₂) ₂]COH	136
CH ₃ CO(CH ₂) ₈ CH=CH ₂ (25 g.)	(+)-CH ₃ (<i>i</i> -C ₆ H ₁₃)CH(CH ₂) ₃ MgBr (35 g. C ₁₁ H ₂₃ Br)	CH ₃ [H ₂ C=CH(CH ₂) ₈][CH ₃ (<i>i</i> -C ₆ H ₁₃)CH(CH ₂) ₃]COH	136
CH ₃ CO(CH ₂) ₈ CH=CH ₂ (18.5 g.)	<i>n</i> -C ₁₂ H ₂₅ MgBr (2.4 g. Mg)	CH ₃ [H ₂ C=CH(CH ₂) ₈](<i>n</i> -C ₁₂ H ₂₅)COH (yielding 18.7 g. diene)	136
<i>t</i> -C ₄ H ₉ COCH=C(CH ₃)- <i>t</i> -C ₄ H ₉	C ₂ H ₅ MgBr	C ₂ H ₅ (<i>t</i> -C ₄ H ₉)[CH ₃ (<i>t</i> -C ₄ H ₉)C=CH]COH (70%)	150
C₁₂H₂₂O₂			
(<i>t</i> -C ₄ H ₉ CO) ₂ CHCH ₃	CH ₃ MgBr	Addition (129/2%); enolization (27/2%)*	124
C₁₂H₂₄O			
C ₂ H ₅ COCH(<i>t</i> -C ₄ H ₉) ₂	<i>t</i> -C ₄ H ₉ MgCl	Recovered ketone (87%) [†]	324
<i>i</i> -C ₄ H ₉ COC(C ₂ H ₅) ₃	CH ₃ MgBr	Addition (0%); enolization (85%)*	168
C₁₂H₂₅ON			
CH ₃ CO(CH ₂) ₂ N(<i>n</i> -C ₄ H ₉) ₂	RMgBr [†]	CH ₃ CR(OH)CH ₂ CH ₂ N(<i>n</i> -C ₄ H ₉) ₂ [†] (15-33%)	253
C₁₃H₇OBr₃			
C ₆ H ₅ COC ₆ H ₂ -2,4,6-Br ₃ (4.5 g., 0.011 mole)	C ₆ H ₅ MgBr (6.5 g., 0.041 mole C ₆ H ₅ Br)	Tar	340

* "Grignard machine" study.

[†] Attributed to substantially complete enolization.[†] R = 1-C₁₀H₇, 4-CH₃O-1-C₁₀H₆, 9-phenanthryl.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₈OBr₂			
(4-BrC ₆ H ₄) ₂ CO	4-ClC ₆ H ₄ MgBr	4-ClC ₆ H ₄ (4-BrC ₆ H ₄) ₂ COH ("low yield")	343
(4-BrC ₆ H ₄) ₂ CO	C ₆ H ₅ MgBr	C ₆ H ₅ (4-BrC ₆ H ₄) ₂ COH	343
(4-BrC ₆ H ₄) ₂ CO (10 g.)	4-ClC ₆ H ₄ CH ₂ MgCl (12 g. C ₇ H ₆ Cl ₂)	4-ClC ₆ H ₄ CH ₂ (4-BrC ₆ H ₄) ₂ COH	387
C₁₃H₈OCl₂			
(4-ClC ₆ H ₄) ₂ CO (0.25 mole)	CH ₃ MgBr (0.25 mole)	CH ₃ (4-ClC ₆ H ₄) ₂ COH (59.3 g., 89%)	348, 349
(4-ClC ₆ H ₄) ₂ CO	CH ₃ MgI	CH ₃ (4-ClC ₆ H ₄) ₂ COH	341
(4-ClC ₆ H ₄) ₂ CO (10 g.)	4-ClC ₆ H ₄ CH ₂ MgCl (14 g. C ₇ H ₆ Cl ₂)	4-ClC ₆ H ₄ CH ₂ (4-ClC ₆ H ₄) ₂ COH (ca. quant.)	387
C₁₃H₈OI₂			
(4-IC ₆ H ₄) ₂ CO (0.5 g.)	4-ClC ₆ H ₄ CH ₂ MgCl (0.7 C ₇ H ₆ Cl ₂)	4-ClC ₆ H ₄ CH ₂ (4-IC ₆ H ₄) ₂ COH (ca. quant.)	387
C₁₃H₉OBr			
4-BrC ₆ H ₄ COC ₆ H ₅	<i>n</i> -C ₃ H ₇ MgBr	4-BrC ₆ H ₄ (C ₆ H ₅)CHOH (24%)*	287
4BrC ₆ H ₄ COC ₆ H ₅	C ₆ H ₅ C≡CMgBr	4-BrC ₆ H ₄ (C ₆ H ₅)(C ₆ H ₅ C≡C)COH (85%)	344
C₁₃H₉OCl			
4-ClC ₆ H ₄ COC ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	4-ClC ₆ H ₄ (C ₆ H ₅)(C ₆ H ₅ CH ₂)COH	345
4-ClC ₆ H ₄ COC ₆ H ₅ (10 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (2 g. Mg)	No apparent reaction	342
C₁₃H₉O₂Br			
Furfurylidene- <i>p</i> -bromoacetophenone	C ₂ H ₅ MgBr	C ₂ H ₅ (α-C ₄ H ₃ O)CHCH ₂ COC ₆ H ₄ -4-Br (95%)	346
Furfurylidene- <i>p</i> -bromoacetophenone	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (α-C ₄ H ₃ O)CHCH ₂ COC ₆ H ₄ -4-Br (80%)	346
Furfurylidene- <i>p</i> -bromoacetophenone	C ₆ H ₅ MgBr	α-C ₄ H ₅ O(C ₆ H ₅)CHCH ₂ COC ₆ H ₄ -4-Br (85%)	346

*From a study of the reducing action of Grignard reagents in which the yields of reduction products only are reported.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₉O₂Cl			
Furfurylidene- <i>p</i> -chloroacetophenone	C ₂ H ₅ MgBr	C ₂ H ₅ (α -C ₄ H ₃ O)CHCH ₂ COC ₆ H ₄ -4-Cl (95%)	346
Furfurylidene- <i>p</i> -chloroacetophenone	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (α -C ₄ H ₃ O)CHCH ₂ COC ₆ H ₄ -4-Cl (72%)	347
Furfurylidene- <i>p</i> -chloroacetophenone	C ₆ H ₅ MgBr	α -C ₄ H ₃ O(C ₆ H ₅)CHCH ₂ C ₆ H ₄ -4-Cl (94%)	347
C₁₃H₁₀O			
(C ₆ H ₅) ₂ CO	CH ₃ MgBr	CH ₃ (C ₆ H ₅) ₂ COH (95%)	605
(C ₆ H ₅) ₂ CO	CH ₃ MgI	CH ₃ (C ₆ H ₅) ₂ COH	350, 287
(C ₆ H ₅) ₂ CO	CH ₃ MgI	(C ₆ H ₅) ₂ C=CH ₂ *	350
(C ₆ H ₅) ₂ CO	(\equiv CMgBr) ₂ (excess)	[\equiv CC(C ₆ H ₅) ₂ OH] ₂ (ca., quant.)	22, 21
(C ₆ H ₅) ₂ CO (0.3 mole) + (CH ₃) ₂ CO (0.2 mole)	(\equiv CMgBr) ₂	[\equiv CC(C ₆ H ₅) ₂ OH] ₂ (34.0 g.); [\equiv CC(CH ₃) ₂ OH] ₂ (2.5 g.); HO(CH ₃) ₂ CC \equiv CC(C ₆ H ₅) ₂ OH	23
(C ₆ H ₅) ₂ CO (0.50 mole) + CH ₃ CHO (0.25 mole)	(\equiv CMgBr) ₂	[\equiv CC(C ₆ H ₅) ₂ OH] ₂ (61 g.); HO(C ₆ H ₅) ₂ CC \equiv CCH(OH)CH ₃ (17 g., 27%)	23
(C ₆ H ₅) ₂ CO (30 g.) + C ₆ H ₅ CHO (20 g.)	(\equiv CMgBr) ₂ (0.5 mole)	[\equiv CC(C ₆ H ₅) ₂ OH] ₂ ; [\equiv CCH(C ₆ H ₅)OH] ₂ (2 isomers); [†] HO(C ₆ H ₅) ₂ CC \equiv CCH(C ₆ H ₅)OH [†]	23
(C ₆ H ₅) ₂ CO	(\equiv CMgBr) ₂	HC \equiv C(C ₆ H ₅) ₂ COH	632
(C ₆ H ₅) ₂ CO	C ₂ H ₅ MgBr	C ₂ H ₅ (C ₆ H ₅) ₂ COH (80%)	287, 199, 215, 389, 611
(C ₆ H ₅) ₂ CO (40 g.)	C ₂ H ₅ MgBr (23.9 g. C ₂ H ₅ Br)	(C ₆ H ₅) ₂ CHOH (30 g.)	388
(C ₆ H ₅) ₂ CO	C ₂ H ₅ MgI	(C ₆ H ₅) ₂ CHOH	388
(C ₆ H ₅) ₂ CO	C ₂ H ₅ MgI	(C ₆ H ₅) ₂ C=CHCH ₃ [‡]	350

* Addition of powdered ketone to Grignard reagent solution; removal of ether; "prolonged" heating at 100°.

[†] Isolated as the corresponding 3,4-dibromo-2,5-dihydrofurans.

[‡] Addition of powdered ketone to cooled Grignard reagent solution; five hours on water-bath.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₁₀O (<i>cont.</i>)			
(C ₆ H ₅) ₂ CO (18.2 g.)	H ₂ C=CHCH ₂ MgBr (100 ml. 1.32 N)	H ₂ C=CHCH ₂ (C ₆ H ₅) ₂ COH (72%); (C ₆ H ₅) ₂ CHOH*	351,28
(C ₆ H ₅) ₂ CO	H ₂ C=CHCH ₂ Br + Mg	H ₂ C=CHCH ₂ (C ₆ H ₅) ₂ COH	279
(C ₆ H ₅) ₂ CO (0.10 mole)	<i>n</i> -C ₃ H ₇ MgBr (0.12 mole C ₃ H ₇ Br)	(C ₆ H ₅) ₂ CHOH (50%)	287
(C ₆ H ₅) ₂ CO	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (C ₆ H ₅) ₂ COH (?) [†]	353
(C ₆ H ₅) ₂ CO	<i>i</i> -C ₃ H ₇ MgBr	(C ₆ H ₅) ₂ CHOH (22%) [‡]	287
(C ₆ H ₅) ₂ CO (in C ₆ H ₆) (70 g.)	<i>i</i> -C ₃ H ₇ MgBr (28.7 g. C ₃ H ₇ Br)	Recovered ketone (nearly complete); <i>no</i> (C ₆ H ₅) ₂ CHOH; <i>i</i> -C ₃ H ₇ C ₆ H ₅ (14 g.)	388
(C ₆ H ₅) ₂ CO	<i>i</i> -C ₃ H ₇ MgI	<i>i</i> -C ₃ H ₇ (C ₆ H ₅) ₂ COH	260
(C ₆ H ₅) ₂ CO	H ₂ C=CHC≡CMgBr	H ₂ C=CHC≡C(C ₆ H ₅) ₂ COH	40
(C ₆ H ₅) ₂ CO	2-Thienyl-MgBr	α-C ₄ H ₃ S(C ₆ H ₅) ₂ COH	41
(C ₆ H ₅) ₂ CO (18 g.)	Pyrryl-MgBr (6.7 g. C ₄ H ₅ N)	α-C ₄ H ₄ N(C ₆ H ₅) ₂ COH	380
(C ₆ H ₅) ₂ CO (18 g.)	Pyrryl-MgBr (13.4 g. C ₄ H ₅ N)	(α-C ₄ H ₄ N) ₂ C(C ₆ H ₅) ₂	380
(C ₆ H ₅) ₂ CO	Butenyl-MgBr	CH ₃ (H ₂ C=CH)CH(C ₆ H ₅) ₂ COH (chiefly) [§]	251
(C ₆ H ₅) ₂ CO	<i>n</i> -C ₄ H ₉ MgBr	(C ₆ H ₅) ₂ CHOH (17-30%); [(C ₆ H ₅) ₂ CH] ₂ O (5.6%)	217
(C ₆ H ₅) ₂ CO (0.10 mole)	<i>n</i> -C ₄ H ₉ MgI (0.12 mole C ₄ H ₉ I)	(C ₆ H ₅) ₂ CHOH (27%) [‡]	287
(C ₆ H ₅) ₂ CO (127.5 g.)	<i>i</i> -C ₄ H ₉ MgBr (170.2 g. C ₄ H ₉ Br)	(C ₆ H ₅) ₂ CHOH (80 g.); [HO(C ₆ H ₅) ₂ C—] ₂ ; [(C ₆ H ₅) ₂ CH] ₂ O; (C ₆ H ₅) ₂ C=CH- <i>i</i> -C ₃ H ₇ (45 g.)	354
(C ₆ H ₅) ₂ CO	<i>i</i> -C ₄ H ₉ MgBr	(C ₆ H ₅) ₂ CHOH (90%)	355,215
(C ₆ H ₅) ₂ CO	<i>i</i> -C ₄ H ₉ MgBr	(C ₆ H ₅) ₂ CHOH (74.3%); (CH ₃) ₂ C=CH ₂ (74.4%)	356

*Probably attributable to atmospheric oxygen contamination of the Grignard reagent (see textual discussion of alkoxide reduction).

[†]The product reported by Klages and Heilmann (353) as the tertiary alcohol is said by Blicke and Powers (287) to be benzhydrol.

[‡]From a study of the reducing action of Grignard reagents in which the yields of reduction products only are reported.

[§]So adjudged because the product, upon thermal decomposition, yields butenes comprising approximately 77% *trans*-2-butene and 23% *cis*-2-butene.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₁₀O (cont.)			
(C ₆ H ₅) ₂ CO	<i>i</i> -C ₄ H ₉ MgI	(C ₆ H ₅) ₂ CHOH (74%)*	287
(C ₆ H ₅) ₂ CO	<i>t</i> -C ₄ H ₉ MgBr	(C ₆ H ₅) ₂ CHOH (38%)	102,357
(C ₆ H ₅) ₂ CO (30 g.)	2-Pyridyl-MgBr	α -C ₅ H ₅ N(C ₆ H ₅) ₂ COH (4 g.)	218
(C ₆ H ₅) ₂ CO	(CH) ₅ MgBr [†]	(CH) ₄ CH(C ₆ H ₅) ₂ COH	358
(C ₆ H ₅) ₂ CO	<i>t</i> -C ₅ H ₁₁ MgBr	(C ₆ H ₅) ₂ CHOH (38%)	102,357
(C ₆ H ₅) ₂ CO	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ (C ₆ H ₅) ₂ COH	359
(C ₆ H ₅) ₂ CO (2.8 g.)	2-BrMgOC ₆ H ₄ MgBr (4 g. C ₂ H ₅ MgBr + 5 g. 2-ClHgC ₆ H ₄ OH)	2-HOC ₆ H ₄ (C ₆ H ₅) ₂ COH (25%, based on RHgCl)	383
(C ₆ H ₅) ₂ CO	4-ClC ₆ H ₄ MgI	4-ClC ₆ H ₄ (C ₆ H ₅) ₂ COH	359
(C ₆ H ₅) ₂ CO (91 g.)	C ₆ H ₅ MgBr (13.5 g. Mg)	(C ₆ H ₅) ₃ COH (ca. 90%)	381,360
(C ₆ H ₅) ₂ CO (45 g.)	CH ₃ CH=CHCH(OMgBr)C \equiv CMgBr (24 g. C ₆ H ₈ O)	CH ₃ CH=CHCH(OH)C \equiv C(C ₆ H ₅) ₂ COH (43 g.)	633,632
(C ₆ H ₅) ₂ CO (5 g.)	<i>t</i> -C ₄ H ₉ C \equiv CMgBr (3 g. <i>t</i> -C ₄ H ₉ C \equiv CH)	<i>t</i> -C ₄ H ₉ C \equiv C(C ₆ H ₅) ₂ COH (7 g.)	310
(C ₆ H ₅) ₂ CO	(CH ₂) ₅ CHMgCl	(C ₆ H ₅) ₂ CHOH; C ₆ H ₁₀	58,59
(C ₆ H ₅) ₂ CO	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CH(C ₆ H ₅) ₂ COH (65%)	619
(C ₆ H ₅) ₂ CO (12 g.)	4-ClC ₆ H ₄ CH ₂ MgCl (20 g. C ₇ H ₆ Cl ₂)	4-ClC ₆ H ₄ CH ₂ (C ₆ H ₅) ₂ COH (ca. quant.)	387
(C ₆ H ₅) ₂ CO (60 g.)	C ₆ H ₅ CH ₂ MgCl (60 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ (C ₆ H ₅) ₂ COH (80-85 g.)	361,199, 362,619
(C ₆ H ₅) ₂ CO (18 g.)	2-CH ₃ C ₆ H ₄ MgBr (25 g. C ₇ H ₇ Br)	2-CH ₃ C ₆ H ₄ (C ₆ H ₅) ₂ COH (8 g.)	364,363, 365
(C ₆ H ₅) ₂ CO (12 g.)	3-CH ₃ C ₆ H ₄ MgBr (20 g. C ₇ H ₇ Br)	3-CH ₃ C ₆ H ₄ (C ₆ H ₅) ₂ COH (8 g.)	364
(C ₆ H ₅) ₂ CO (8 g.)	4-CH ₃ C ₆ H ₄ MgBr (10 g. C ₇ H ₇ Br)	4-CH ₃ C ₆ H ₄ (C ₆ H ₅) ₂ COH (3.25 g.)	364,365
(C ₆ H ₅) ₂ CO	2-CH ₃ OC ₆ H ₄ MgBr	2-CH ₃ OC ₆ H ₄ (C ₆ H ₅) ₂ COH	619

*From a study of the reducing action of Grignard reagents in which the yields of reduction products only are reported.

[†]5-Cyclopentadienylmagnesium bromide.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₁₀O (<i>cont.</i>)			
(C ₆ H ₅) ₂ CO	4-CH ₃ OC ₆ H ₄ MgBr	4-CH ₃ OC ₆ H ₄ (C ₆ H ₅) ₂ COH (60%)	365
(C ₆ H ₅) ₂ CO	<i>n</i> -C ₅ H ₁₁ C≡CMgBr	<i>n</i> -C ₅ H ₁₁ C≡C(C ₆ H ₅) ₂ COH	65
(C ₆ H ₅) ₂ CO	(C ₂ H ₅) ₂ N(CH ₂) ₃ MgCl	(C ₂ H ₅) ₂ N(CH ₂) ₃ C(C ₆ H ₅) ₂ OH (66%)	366, 390
(C ₆ H ₅) ₂ CO (18 g.)	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl (30 g.) + Mg (4.8 g.)	(C ₂ H ₅) ₂ N(CH ₂) ₃ C(C ₆ H ₅) ₂ OH	226
(C ₆ H ₅) ₂ CO	C ₆ H ₅ C≡CMgBr	C ₆ H ₅ C≡C(C ₆ H ₅) ₂ COH (79%)	367, 664 660, 663, 36
(C ₆ H ₅) ₂ CO	2-ClC ₆ H ₄ CH(CO ₂ MgCl)MgCl*	2-ClC ₆ H ₄ CH(CO ₂ H)C(C ₆ H ₅) ₂ OH	149
(C ₆ H ₅) ₂ CO (12.2 g.)	3-ClC ₆ H ₄ CH(CO ₂ MgCl)MgCl* (8.3 g. 3-ClC ₆ H ₄ CH ₂ CO ₂ H)	3-ClC ₆ H ₄ CH(CO ₂ H)C(C ₆ H ₅) ₂ OH (13.2 g.)	384
(C ₆ H ₅) ₂ CO	2-Benzothiazolylmethyl-MgBr	2-C ₆ H ₄ NSCH ₂ (C ₆ H ₅) ₂ COH	385
(C ₆ H ₅) ₂ CO	C ₆ H ₅ CH(CO ₂ Na)MgX*	C ₆ H ₅ CH(CO ₂ H)C(C ₆ H ₅) ₂ OH ("good yield")	200
(C ₆ H ₅) ₂ CO	C ₆ H ₅ CH=CHMgBr	C ₆ H ₅ CH=CH(C ₆ H ₅) ₂ COH (?) [†] (14%)	369; <i>c.f.</i> 370
(C ₆ H ₅) ₂ CO	C ₆ H ₅ (CH ₂) ₂ MgBr	C ₆ H ₅ CH ₂ CH ₂ (C ₆ H ₅) ₂ COH	619
(C ₆ H ₅) ₂ CO (40 g.)	2-C ₂ H ₅ C ₆ H ₄ MgBr (42 g. C ₈ H ₉ Br)	2-C ₂ H ₅ C ₆ H ₄ (C ₆ H ₅) ₂ COH (32 g.)	382
(C ₆ H ₅) ₂ CO	4-(CH ₃) ₂ NC ₆ H ₄ MgBr	4-(CH ₃) ₂ NC ₆ H ₄ (C ₆ H ₅) ₂ COH	371
(C ₆ H ₅) ₂ CO	CH ₃ (C ₂ H ₅) ₂ CC≡CMgBr	CH ₃ (C ₂ H ₅) ₂ CC≡C(C ₆ H ₅) ₂ COH (71%)	372
(C ₆ H ₅) ₂ CO	(CH ₂) ₅ N(CH ₂) ₃ MgCl	(CH ₂) ₅ N(CH ₂) ₃ C(C ₆ H ₅) ₂ OH	366, 226

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931); this "Grignard reagent" should be formulated as an enolate.

[†]The product, purified by methanol crystallization by Meyer and Scuster (369), and by them ascribed the carbinol constitution formulated above, is said by Straus and Eherenstein (370) to be the high-melting form of the methyl ether, (C₆H₅)₂C=CHCH(OCH₃)C₆H₅. The probable course of the rearrangement is discussed.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₁₀O (<i>cont.</i>)			
(C ₆ H ₅) ₂ CO	1-Indenyl-Mg Br	α -C ₉ H ₇ (C ₆ H ₅) ₂ COH (82%)	69
(C ₆ H ₅) ₂ CO	4-CH ₃ C ₆ H ₄ C \equiv CMgBr	4-CH ₃ C ₆ H ₄ C \equiv C(C ₆ H ₅) ₂ COH (62%)	65
(C ₆ H ₅) ₂ CO (5.0 g.)	3-Thianaphthenylmethyl-MgCl	3-Benzhydrylidene-methylthianaphthene (1.64 g., 19%)	659
(C ₆ H ₅) ₂ CO (75 g.)	4- <i>n</i> -C ₃ H ₇ C ₆ H ₄ MgBr (100 g. C ₉ H ₁₁ Br)	4- <i>n</i> -C ₃ H ₇ C ₆ H ₄ (C ₆ H ₅) ₂ COH (yielding 24 g. chloride)	382
(C ₆ H ₅) ₂ CO	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ MgBr	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ (C ₆ H ₅) ₂ COH	363
(C ₆ H ₅) ₂ CO	1-C ₁₀ H ₇ MgBr	1-C ₁₀ H ₇ (C ₆ H ₅) ₂ COH	368, 365
(C ₆ H ₅) ₂ CO (88 g.)	4- <i>i</i> -C ₄ H ₉ C ₆ H ₄ MgBr (107 g. C ₁₀ H ₁₃ Br)	4- <i>i</i> -C ₄ H ₉ C ₆ H ₄ (C ₆ H ₅) ₂ COH (yielding 26 g. chloride)	382
(C ₆ H ₅) ₂ CO (85 g.)	4- <i>s</i> -C ₄ H ₉ C ₆ H ₄ MgBr (107 g. C ₁₀ H ₁₃ Br)	4- <i>s</i> -C ₄ H ₉ C ₆ H ₄ (C ₆ H ₅) ₂ COH (yielding 22 g. chloride)	382
(C ₆ H ₅) ₂ CO	α -Camphoryl-MgBr*	α -C ₁₀ H ₁₅ O(C ₆ H ₅) ₂ COH (70%)	75
(C ₆ H ₅) ₂ CO (47 g.)	3- <i>n</i> -C ₅ H ₁₁ C ₆ H ₄ MgBr (66 g. C ₁₁ H ₁₅ Br)	3- <i>n</i> -C ₅ H ₁₁ C ₆ H ₄ (C ₆ H ₅) ₂ COH (yielding 13 g. chloride)	382
(C ₆ H ₅) ₂ CO (40 g.)	4- <i>t</i> -C ₅ H ₁₁ C ₆ H ₄ MgBr (57 g. C ₁₁ H ₁₅ Br)	4- <i>t</i> -C ₅ H ₁₁ C ₆ H ₄ (C ₆ H ₅) ₂ COH (yielding 11 g. chloride)	382
(C ₆ H ₅) ₂ CO	(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₃ MgCl	(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₃ C(C ₆ H ₅) ₂ OH	366, 226, 390
(C ₆ H ₅) ₂ CO	2-C ₁₀ H ₇ C \equiv CMgBr	2-C ₁₀ H ₇ C \equiv C(C ₆ H ₅) ₂ COH (50%)	65
(C ₆ H ₅) ₂ CO (6.1 g.)	1-C ₁₀ H ₇ CH(CO ₂ MgCl)MgCl [†] (4.2 g. 1-C ₁₀ H ₇ CH ₂ CO ₂ H)	HO ₂ C(1-C ₁₀ H ₇)CH(C ₆ H ₅) ₂ COH	384
(C ₆ H ₅) ₂ CO	4-C ₆ H ₅ C ₆ H ₄ MgBr	4-C ₆ H ₅ C ₆ H ₄ (C ₆ H ₅) ₂ COH	373

*Probably this "Grignard reagent" is an enolate.

[†]In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₃H₁₀O (<i>cont.</i>)			
(C ₆ H ₅) ₂ CO	4-C ₆ H ₅ C ₆ H ₄ MgI	4-C ₆ H ₅ C ₆ H ₄ (C ₆ H ₅) ₂ COH*	375
(C ₆ H ₅) ₂ CO	5-Acenaphthenyl-MgBr	5-C ₁₂ H ₉ (C ₆ H ₅) ₂ COH	374
(C ₆ H ₅) ₂ CO	9-Fluorenyl-MgBr	9-C ₁₃ H ₉ (C ₆ H ₅) ₂ COH	376
(C ₆ H ₅) ₂ CO (2 g.)	9-Anthryl-MgBr (2.5 g. C ₁₄ H ₉ Br)	9-C ₁₄ H ₉ (C ₆ H ₅) ₂ COH (36%)	386
(C ₆ H ₅) ₂ CO	9-Phenanthryl-MgBr	9-C ₁₄ H ₉ (C ₆ H ₅) ₂ COH (76%)	377
(C ₆ H ₅) ₂ CO	(C ₆ H ₅) ₂ C=CHMgBr	(C ₆ H ₅) ₂ C=CH(C ₆ H ₅) ₂ COH (75%)	378
(C ₆ H ₅) ₂ CO (2 g.)	4-C ₆ H ₅ C ₆ H ₄ CH=C(C ₆ H ₅)MgBr (5 g. C ₂₀ H ₁₅ Br)	4-C ₆ H ₅ C ₆ H ₄ CH=C(C ₆ H ₅)C(C ₆ H ₅) ₂ OH (1.75 g.)	379
(C ₆ H ₅) ₂ CO (5 g.)	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)MgBr (10 g. C ₂₀ H ₁₅ Br)	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)C(C ₆ H ₅) ₂ OH (3.1 g.); tetraphenylindene (2.25 g.)	379
C₁₃H₁₀OBrN			
C ₆ H ₅ COC ₆ H ₃ -2-NH ₂ -5-Br (5 g.)	CH ₃ MgI (12 g. CH ₃ I)	CH ₃ (C ₆ H ₅)(2-H ₂ N-5-BrC ₆ H ₃)COH	391
C₁₃H₁₀O₂			
(α-C ₄ H ₁₃ O)CH=CHCOC ₆ H ₅ †	RmgX‡.	(C ₄ H ₃ O)CHRCH ₂ COC ₆ H ₅	624
C₁₃H₁₀O₂ClN			
4-HOC ₆ H ₄ COC ₆ H ₃ -2-NH ₂ -5-Cl (10 g.)	CH ₃ MgI (40 g. CH ₃ I)	4-HOC ₆ H ₄ (2-H ₂ N-5-ClC ₆ H ₃)C=CH ₂ (6.7 g.)	391
C₁₃H₁₀O₃			
C ₆ H ₅ COC ₆ H ₃ -2,4-(OH) ₂	C ₆ H ₅ MgBr	2,4-(HO) ₂ C ₆ H ₃ (C ₆ H ₅) ₂ COH	392,394, 395

* According to Schlenk and Weickel (375), the yield of carbinol obtained is dependent primarily upon the quality of the iodine-activated magnesium employed in preparation of the Grignard reagent.

† Furfurylideneacetophenone.

‡ RMgX = CH₃MgI, C₂H₅MgBr, C₆H₅MgBr.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₁₀O₃ (cont.)			
2-HOC ₆ H ₄ COC ₆ H ₄ -4-OH	C ₆ H ₅ MgBr	C ₆ H ₅ (2-HOC ₆ H ₄)(4-HOC ₆ H ₄)COH	394
3-HOC ₆ H ₄ COC ₆ H ₄ -4-OH	C ₆ H ₅ MgBr	C ₆ H ₅ (3-HOC ₆ H ₄)(4-HOC ₆ H ₄)COH	394
(3-HOC ₆ H ₄) ₂ CO	C ₆ H ₅ MgBr	C ₆ H ₅ (3-HOC ₆ H ₄) ₂ COH	394
C₁₃H₁₁ON			
C ₆ H ₅ COC ₆ H ₄ -2-NH ₂ (20 g.)	CH ₃ MgI (60 g. CH ₃ I)	CH ₃ (C ₆ H ₅)(2-H ₂ NC ₆ H ₄)COH (<i>ca.</i> quant.)	397,396
C ₆ H ₅ COC ₆ H ₄ -2-NH ₂ (14 g.)	C ₂ H ₅ MgI	C ₂ H ₅ (C ₆ H ₅)(2-H ₂ NC ₆ H ₄)COH (15.6 g.)	398
C ₆ H ₅ COC ₆ H ₄ -4-NH ₂ (2.00 g.)	C ₂ H ₅ MgBr (6.72 g. C ₂ H ₅ Br)	C ₂ H ₅ (C ₆ H ₅)(4-H ₂ NC ₆ H ₄)COH	389
C ₆ H ₅ COC ₆ H ₄ -4-NH ₂ (2.0 g.)	<i>i</i> -C ₃ H ₇ MgBr (7.5 g. C ₃ H ₇ Br)	<i>i</i> -C ₃ H ₇ (C ₆ H ₅)(4-N ₂ NC ₆ H ₄)COH ("a little"); recovered ketone	389
C ₆ H ₅ COC ₆ H ₄ -4-NH ₂ (2.0 g.)	<i>n</i> -C ₄ H ₉ MgBr (11.2 g. C ₄ H ₉ Br)	<i>n</i> -C ₄ H ₉ (C ₆ H ₅)(4-H ₂ NC ₆ H ₄)COH	389
C₁₃H₁₂O			
1-CH ₃ COC ₁₀ H ₆ -4-CH ₃	CH ₃ MgI	1-[HO(CH ₃) ₂ C]C ₁₀ H ₆ -4-CH ₃	399
C₁₃H₁₂O₂			
CH ₃ COCH ₂ O-2-C ₁₀ H ₇	2-C ₆ H ₅ C ₆ H ₄ MgI	ClI ₃ (2-C ₁₀ H ₇ OCH ₂)(2-C ₆ H ₅ C ₆ H ₄)COH	16
C₁₃H₁₄O₂			
2- <i>p</i> -Toluylcyclopentanone	C ₂ H ₅ MgBr	2-(<i>α-p</i> -Tolylpropylidene)cyclopentanone; 1-ethyl-2- <i>p</i> -toluylcyclopentene	400
C₁₃H₁₅OCl			
C ₆ H ₅ COCCL(CH ₂) ₅	CH ₃ MgX	CH ₃ COC(C ₆ H ₅)(CH ₂) ₅ ; no chlorohydrin isolable	237
C₁₃H₁₆O			
CH ₃ COCH=CHC ₆ H ₄ -2,4,6-(CH ₃) ₃	RMgX	R(CH ₃)[2,4,6-(CH ₃) ₃ C ₆ H ₂ CH=CH]COH; CH ₃ COCH ₂ CHRC ₆ H ₄ -2,4,6-(CH ₃) ₃	401

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₃H₁₆O (<i>cont.</i>)			
CH ₃ CH=CHCOC ₆ H ₂ -2,4,6-(CH ₃) ₃ (6.15 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (14.60 g. C ₉ H ₁₁ Br)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂ CH(CH ₃)C ₆ H ₂ -2,4,6- (CH ₃) ₃ (7 g.)	393
<i>t</i> -C ₄ H ₉ COCH=CHC ₆ H ₅ (30 g.)	C ₂ H ₅ MgBr	<i>t</i> -C ₄ H ₉ COCH ₂ CH(C ₂ H ₅)C ₆ H ₅ (34 g.)	111
<i>t</i> -C ₄ H ₉ COCH=CHC ₆ H ₅ (30 g.)	C ₆ H ₅ MgBr	<i>t</i> -C ₄ H ₉ COCH ₂ CH(C ₆ H ₅) ₂ (41 g.)	111
C₁₃H₁₆O₂			
2-Methyl-2-benzoyl-3,5-epoxypentane	C ₆ H ₅ MgBr	1,1-Diphenyl-2,2-dimethyl-4,5-epoxy-1- pentanol	665
C₁₃H₁₆O₃			
H ₃ CO ₂ C(CH ₂) ₂ COC ₆ H ₃ -3,4-(CH ₃) ₂	CH ₃ MgI	3,4-(CH ₃) ₂ C ₆ H ₃ C(CH ₃)=CHCH ₂ CO ₂ CH ₃ (62%)	402
H ₃ CO ₂ CCH(CH ₃)CH ₂ COC ₆ H ₄ -4-CH ₃ (11.0 g.)	CH ₃ MgI (15.0 g. CH ₃ I)	4-CH ₃ C ₆ H ₄ C(CH ₃)=CHCH(CH ₃)CO ₂ H (9.0-9.5 g., 90-95%)	615
H ₅ C ₂ O ₂ C(CH ₂) ₂ COC ₆ H ₄ -4-CH ₃ (11.0 g.)	C ₂ H ₅ MgBr (8.0 ml. C ₂ H ₅ Br)	4-CH ₃ C ₆ H ₄ C(C ₂ H ₅)=CHCH ₂ CO ₂ H (75%)	616
C₁₃H₁₇O₂Cl			
C ₂ H ₅ COC ₆ H-2,4-(CH ₃) ₂ -3-Cl-6-OC ₂ H ₅	C ₂ H ₅ MgBr (+ CO ₂)	2,4-(CH ₃) ₂ -3-Cl-6-C ₂ H ₅ OC ₆ HCOCH(CH ₃)CO ₂ H (41%)	315
C₁₃H₁₈O			
<i>i</i> -C ₃ H ₇ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	Butenyl-MgBr	<i>i</i> -C ₃ H ₇ [CH ₃ (H ₂ C=CH)CH][2,4,6- (CH ₃) ₃ C ₆ H ₂]COH (chiefly)*	251
C ₆ H ₅ CO- <i>n</i> -C ₆ H ₁₃	C ₆ H ₅ MgBr	<i>n</i> -C ₆ H ₁₃ (C ₆ H ₅) ₂ COH	353
CH ₃ (C ₂ H ₅) ₂ CCOC ₆ H ₅	CH ₃ MgI	CH ₃ (C ₆ H ₅)[CH ₃ (C ₂ H ₅) ₂ C]COH	234

*So adjudged because thermal decomposition of the product yielded $6 \pm 5\%$ of 1-butene, $24 \pm 5\%$ of *trans*-2-butene, and $70 \pm 5\%$ of *cis*-2-butene, as evaluated by absorption spectrum measurements.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₃H₁₈O (<i>cont.</i>)			
CH ₃ (C ₂ H ₅) ₂ CCOC ₆ H ₅	C ₆ H ₅ MgBr	CH ₃ (C ₂ H ₅) ₂ C(C ₆ H ₅) ₂ COH* (75%)	234
CH ₃ (C ₂ H ₅) ₂ CCOC ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ [CH ₃ (C ₂ H ₅) ₂ C](C ₆ H ₅ CH ₂)COH †	234
C₁₃H₁₈O₂			
C ₂ H ₅ COCH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃	CH ₃ MgI	CH ₃ (C ₂ H ₅)[C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)CH]COH	173
C ₂ H ₅ COCH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃	CH ₃ O(C ₂ H ₅)CH(CH ₂) ₂ MgCl	C ₂ H ₅ [CH ₃ O(C ₂ H ₅)CH(CH ₂) ₂][C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)CH]COH	408
(C ₂ H ₅) ₂ CHCOC ₆ H ₄ -4-OCH ₃	4-CH ₃ OC ₆ H ₄ MgBr	(C ₂ H ₅) ₂ CH(4-CH ₃ OC ₆ H ₄) ₂ COH	404
C₁₃H₁₈O₄			
Ethyl furoyldiethylacetate	C ₂ H ₅ MgBr	C ₄ H ₃ O(C ₂ H ₅) ₂ COH	319
Ethyl furoyldiethylacetate	C ₆ H ₅ MgBr	C ₄ H ₃ O(C ₆ H ₅) ₂ COH	319
C₁₃H₂₀O			
Pseudoionone †	(—CH ₂ CH ₂ Br) ₂ + Mg	Dehydrosqualene §	634
Pseudoionone † (28.8 g.)	CH ₃ O(CH ₂) ₃ Br (25 g.) + Mg (4.4 g.)	1-Methoxy-4,8,12-trimethyltrideca-3,5,7,11-tetraene (19.9 g., 53.5%)	409
Pseudoionone † (96.0 g., 0.5 mole)	C ₂ H ₅ O(CH ₂) ₃ Br (100.0 g., 0.6 mole) + Mg (15.2 g., 0.625 mole)	1-Ethoxy-4,8,12-trimethyltrideca-3,5,7,11-tetraene (52%)	409
Pseudoionone † (15.6 g.)	C ₆ H ₅ O(CH ₂) ₃ Br (22.9 g.) + Mg (2.7 g.)	1-Benzoyloxy-4,8,12-trimethyltrideca-3,5,7,11-tetraene (12.8 g., 49%)	409

*This carbinol, upon distillation at ordinary pressure, decomposes into (C₆H₅)₂CO + CH₃CH=C(C₂H₅)₂.

†This carbinol, upon distillation at ordinary pressure, decomposes into C₆H₅COCH₂C₆H₅ + CH₃CH=C(C₂H₅)₂.

‡CH₃COCH=CHCH=C(CH₃)CH₂CH₂CH=C(CH₃)₂.

§[(CH₃)₂C=CH(CH₂)₂C(CH₃)=CHCH=CHC(CH₃)=CHCH₂—]₂.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₃H₂₀O (cont.)			
α -Ionone* (35.0 g.)	H ₂ C=CHCH ₂ Br (36.0 g.) + Mg (7.3 g.)	2,4,4-Trimethyl-3-(3-hydroxy-3-methyl-1,5-hexadienyl)cyclohexene (28.0 g., crude)	635
α -Ionone* (3.5 g.)	CH ₃ CH=C(CH ₃)CH=CHCH ₂ Br (3.0 g.) + Mg (0.5 g.)	2,4,4-Trimethyl-3-(3-hydroxy-3,7-dimethyl-1,5,7-nonatrienyl)cyclohexene	95
β -Ionone [†]	CH ₃ MgI	Ionene [‡] ; CH ₄	405
β -Ionone [†]	H ₂ C=CHCH ₂ Br + Mg	"Little or no carbinol"	635
β -Ionone [†] (0.125 mole)	H ₂ C=CHC≡CMgBr (0.150 mole C ₄ H ₄)	R(CH ₃)(H ₂ C=CHC≡C)COH [§] (59%)	636, 637
β -Ionone [†] (40 g.)	C ₂ H ₅ OC≡CMgBr (6.3 g. C ₂ H ₅ OC≡CH)	R(CH ₃)(H ₂ C ₅ OC≡C)COH [§] (8.5 g., 73%)	233, 487
β -Ionone [†]	(=CHCH ₂ Br) ₂ + Mg	[R(CH ₃)(HO)CCH ₂ CH=] ₂ [§]	638
β -Ionone [†]	H ₅ C ₂ O ₂ CCH ₂ Br + Mg	Ionene [‡] ; R(CH ₃)C=CHCO ₂ C ₂ H ₅ [§]	405
β -Ionone [†]	<i>i</i> -C ₄ H ₉ MgBr	Ionene [‡] ; <i>i</i> -C ₄ H ₁₀	405
β -Ionone [†] (0.125 mole)	H ₂ C=C(CH ₃)C≡CMgBr (0.150 mole C ₅ H ₆)	R(CH ₃)[H ₂ C=C(CH ₃)C≡C]COH [§] (48%)	636
β -Ionone [†] (0.125 mole)	CH ₃ CH=C(CH ₃)C≡CMgBr (0.150 mole C ₆ H ₈)	R(CH ₃)[CH ₃ CH=C(CH ₃)C≡C]COH [§] (52%)	636
β -Ionone [†] (20.0 g.)	(C ₂ H ₅ O) ₂ CHCH ₂ Br (21.6 g.) + Mg	R(CH ₃)C=CHCHO [§] (14.7 g., 64%)	639
C₁₃H₂₀O₂			
5- α -Furyl-8-methyl-2-nonanone	<i>i</i> -C ₅ H ₁₁ MgI	CH ₃ (<i>i</i> -C ₅ H ₁₁)[α -C ₄ H ₃ O(<i>i</i> -C ₅ H ₁₁)CHCH ₂]COH (38%)	405

*2,4,4-Trimethyl-3-(β -acetovinyl)cyclohexene.[†]1,3,3-Trimethyl-2-(β -acetovinyl)cyclohexene.[‡]1,1,6-Trimethyltetralin.[§]R = β -(2,6,6-trimethyl-1-cyclohexenyl)vinyl.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₃H₂₂O			
Geranylacetone*	(—CH ₂ CH ₂ Br) ₂ + Mg	Squalene†	406
[(CH ₂) ₅ CH] ₂ CO	C ₆ H ₅ MgBr	C ₆ H ₅ [(CH ₂) ₅ CH] ₂ COH	406
[(CH ₂) ₅ CH] ₂ CO	(CH ₂) ₅ CHMgCl	[(CH ₂) ₅ CH] ₂ CHOH; cyclohexene	59
C₁₃H₂₄O			
CH ₃ CO(CH ₂) ₉ CH=CH ₂ (9.4 g.)	CH ₃ (<i>n</i> -C ₄ H ₉)CH(CH ₂) ₅ MgBr	CH ₃ [H ₂ C=CH(CH ₂) ₉][CH ₃ (<i>n</i> -C ₄ H ₉)CH(CH ₂) ₅]COH (8.6 g., crude)	136
CH ₃ COCH(<i>n</i> -C ₄ H ₉)CH=CH- <i>t</i> -C ₄ H ₉ (28 g.)	<i>n</i> -C ₈ H ₁₇ MgBr (40 g. C ₈ H ₁₇ Br)	CH ₃ (<i>n</i> -C ₈ H ₁₇)[<i>n</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉ CH=CH)CH]COH (11 g.); CH ₃ [<i>n</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉ CH=CH)CH]CHOH (9 g.); H ₂ C=CH- <i>n</i> -C ₆ H ₁₃ (6 g.)	388
Tetrahydroionone‡	H ₂ C=CHC≡CMgBr	1-(2,2,6-Trimethylcyclohexyl)-3-methylhept-4-yn-6-en-3-ol (80%)	636
Tetrahydroionone‡ (7.40 g.)	C ₂ H ₅ OC≡CMgBr (2.64 g. C ₄ H ₆ BrO)	1-Ethoxy-3-methyl-5-(2,2,6-trimethylcyclohexyl)-1-pentyn-3-ol	410
Tetrahydroionone‡	H ₂ C=C(CH ₃)C≡CMgBr	1-(2,2,6-Trimethylcyclohexyl)-3,6-dimethylhept-4-yn-6-en-3-ol (80%)	636
Tetrahydroionone‡	CH ₃ CH=C(CH ₃)C≡CMgBr	1-(2,2,6-Trimethylcyclohexyl)-3,6-dimethyloct-4-yn-6-en-3-ol (80%)	636
C₁₃H₂₄O₃			
CH ₃ CO(CH ₂) ₈ CO ₂ C ₂ H ₅	<i>n</i> -C ₁₂ H ₂₅ MgBr	After hydrogen'n: <i>n</i> -C ₁₂ H ₂₅ CH(CH ₃)(CH ₂) ₈ CO ₂ H	407

*CH₃CO(CH₂)₂CH=C(CH₃)(CH₂)₂CH=C(CH₃)₂.†[(CH₃)₂C=CH(CH₂)₂C(CH₃)=CH(CH₂)₂C(CH₃)=CHCH₂—]₂.

‡1,1,3-Trimethyl-2-(β-acetoethyl)cyclohexane.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₂₄O₅ (cont.)			
CH ₃ CO(CH ₂) ₈ CO ₂ C ₂ H ₅	<i>n</i> -C ₁₄ H ₂₉ MgBr	After hydrogen'n: <i>n</i> -C ₁₄ H ₂₉ CH(CH ₃)(CH ₂) ₈ CO ₂ H	407
CH ₃ CO(CH ₂) ₈ CO ₂ C ₂ H ₅	<i>n</i> -C ₁₄ H ₂₉ MgBr	CH ₃ [H ₅ C ₂ O ₂ C(CH ₂) ₈](<i>n</i> -C ₁₄ H ₂₉)COH	269
CH ₃ CO(CH ₂) ₈ CO ₂ C ₂ H ₅	<i>n</i> -C ₁₆ H ₃₃ MgBr	After hydrogen'n: <i>n</i> -C ₁₆ H ₃₃ CH(CH ₃)(CH ₂) ₈ CO ₂ H	407
C₁₃H₂₆O			
CH ₃ CO(CH ₂) ₃ CH(CH ₃)- <i>i</i> -C ₆ H ₁₃ (96 g.)	C ₂ H ₅ O(CH ₂) ₃ Br (100 g.) + Mg (15.2 g.)	C ₂ H ₅ O(CH ₂) ₂ CH=C(CH ₃)(CH ₂) ₃ CH(CH ₃)- <i>i</i> - C ₆ H ₁₃ (52%)	411
(<i>n</i> -C ₆ H ₁₃) ₂ CO	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ (<i>n</i> -C ₆ H ₁₃) ₂ COH	298
(<i>n</i> -C ₆ H ₁₃) ₂ CO	<i>n</i> -C ₈ H ₁₇ MgBr	<i>n</i> -C ₈ H ₁₇ (<i>n</i> -C ₆ H ₁₃) ₂ COH	298
C₁₄H₈O₂Br₂			
(4-BrC ₆ H ₄ CO—) ₂	(≡CMgBr) ₂	[HO(4-BrC ₆ H ₄)(4-BrC ₆ H ₄ CO)CC≡] ₂ ; HO(4-BrC ₆ H ₄)(4-BrC ₆ H ₄ CO)CC≡CH	85
C₁₄H₁₀O			
(C ₆ H ₅) ₂ C=CO	C ₆ H ₅ MgBr (1.5 equiv.)	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)OH	445,425
(C ₆ H ₅) ₂ C=CO (9.7 g.)	C ₆ H ₅ C≡CMgBr (5.5 ml. C ₆ H ₅ C≡CH)	C ₆ H ₅ C≡CCOCH(C ₆ H ₅) ₂ (12 g., crude)	446
C₁₄H₁₀O₂			
(C ₆ H ₅ CO—) ₂	CH ₃ MgI	[HO(CH ₃)(C ₆ H ₅)C—] ₂ , m.p. 118° (52%); isomer, m.p. 45°	413,439
(C ₆ H ₅ CO—) ₂	(≡MgBr) ₂ (1 equiv.)	[HO(C ₆ H ₅)(C ₆ H ₅ CO)CC≡] ₂	412
(C ₆ H ₅ CO—) ₂	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ (C ₆ H ₅)(C ₆ H ₅ CO)COH (0.5–5.6%); C ₆ H ₅ CH(OH)COC ₆ H ₅ (0.5–13.0%)	217

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₀O₂ (cont.)			
(C ₆ H ₅ CO—) ₂	H ₂ C=CHCH ₂ Br + Mg	[HO(H ₂ C=CHCH ₂)(C ₆ H ₅)C—] ₂ (25-30%)	86
(C ₆ H ₅ CO—) ₂	4-BrC ₆ H ₄ MgBr (ca. 1 equiv.)	4-BrC ₆ H ₄ (C ₆ H ₅)(C ₆ H ₅ CO)COH	359
(C ₆ H ₅ CO—) ₂	4-BrC ₆ H ₄ MgBr (ca. 2 equiv.)	[HO(4-BrC ₆ H ₄)(C ₆ H ₅)C—] ₂	359
(C ₆ H ₅ CO—) ₂ (7 g.)	4-ClC ₆ H ₄ MgI (10 g. C ₆ H ₄ ClI)	4-ClC ₆ H ₄ (C ₆ H ₅)(C ₆ H ₅ CO)COH	359
(C ₆ H ₅ CO—) ₂ (5 g.)	4-ClC ₆ H ₄ MgI (15 g. C ₆ H ₄ ClI)	[HO(4-ClC ₆ H ₄)(C ₆ H ₅)C—] ₂	359
(C ₆ H ₅ CO—) ₂ (50. g.)	(CH ₂) ₅ CHMgCl (120 g. C ₆ H ₁₁ Cl)	{HO(C ₆ H ₅)[(CH ₂) ₅ CH]C—} ₂ (ca. quant.)	440
(C ₆ H ₅ CO—) ₂	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ (C ₆ H ₅ CH ₂)(C ₆ H ₅ CO)COH; C ₆ H ₅ CH(OH)COC ₆ H ₅ ; (C ₆ H ₅ CH ₂ —) ₂	362
(C ₆ H ₅ CO—) ₂	C ₆ H ₅ CH ₂ MgCl	[HO(C ₆ H ₅)(C ₆ H ₅ CH ₂)C—] ₂	435
(C ₆ H ₅ CO—) ₂ (21 g.)	2-CH ₃ C ₆ H ₄ MgBr (20 g. C ₇ H ₇ Br)	2-CH ₃ C ₆ H ₄ COC(C ₆ H ₅) ₂ OH (?) (8 g.)	414
(C ₆ H ₅ CO—) ₂ (21 g.)	3-CH ₃ C ₆ H ₄ MgBr (25 g. C ₇ H ₇ Br)	C ₆ H ₅ (C ₆ H ₅ CO)(3-CH ₃ C ₆ H ₄)COH (4 g.); C ₆ H ₅ CH(OH)COC ₆ H ₅ ; recovered benzil	414
(C ₆ H ₅ CO—) ₂	4-CH ₃ C ₆ H ₄ MgBr	Product yielding, on HI-P red'n, C ₆ H ₅ (4-CH ₃ C ₆ H ₄)CHCOC ₆ H ₅ *	414
(C ₆ H ₅ CO—) ₂	4-CH ₃ C ₆ H ₄ MgBr	Two isomeric pinacolins [†]	414
(C ₆ H ₅ CO—) ₂	4-C ₂ H ₅ OC ₆ H ₄ MgBr	[HO(C ₆ H ₅)(4-C ₂ H ₅ OC ₆ H ₄)C—] ₂ (41%)	415
(C ₆ H ₅ CO—) ₂ (10.5 g.)	2-(<i>p</i> -ClC ₆ H ₄)C ₆ H ₄ MgI (18.9 g. C ₁₂ H ₈ ClI)	C ₆ H ₅ (C ₆ H ₅ CO)(2- <i>p</i> -ClC ₆ H ₄ C ₆ H ₄)COH (6.6 g., 33%)	421
(C ₆ H ₅ CO—) ₂ (10.5 g.)	2-C ₆ H ₅ C ₆ H ₄ MgI (16.8 g. C ₁₂ H ₉ I)	C ₆ H ₅ (C ₆ H ₅ CO)(2-C ₆ H ₅ C ₆ H ₄)COH (9.04 g., 50%)	421
α -Furfurylidene- <i>p</i> -methylacetophenone (45 g.)	CH ₃ MgI (0.5 mole CH ₃ I)	CH ₃ (α -C ₄ H ₃ O)CHCH ₂ COC ₆ H ₄ -4-CH ₃ (50%)	346
α -Furfurylidene- <i>p</i> -methylacetophenone (45 g.)	C ₂ H ₅ MgBr (60 g. C ₂ H ₅ Br)	C ₂ H ₅ (α -C ₄ H ₃ O)CHCH ₂ COC ₆ H ₄ -4-CH ₃ (50 g.)	346
α -Furfurylidene- <i>p</i> -methylacetophenone (45 g.)	<i>i</i> -C ₃ H ₇ MgBr (0.5 mole C ₃ H ₇ Br)	<i>i</i> -C ₃ H ₇ (α -C ₄ H ₃ O)CHCH ₂ COC ₆ H ₄ -4-CH ₃ (80%).	346

*Addition of Grignard reagent solution to ether-benzil solution; one hour reflux.

[†]Addition of ether-benzil solution to Grignard reagent solution; one hour reflux.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₀O₂ (cont.)			
α -Furfurylidene- <i>p</i> -methylacetophenone (45 g.)	<i>i</i> -C ₄ H ₉ MgBr (0.5 mole C ₄ H ₉ Br)	α -C ₄ H ₃ O(<i>i</i> -C ₄ H ₉)CHCH ₂ COC ₆ H ₄ -4-CH ₃ (70%)	346
α -Furfurylidene- <i>p</i> -methylacetophenone (45 g.)	C ₆ H ₅ MgBr (80 g. C ₆ H ₅ Br)	α -C ₄ H ₃ O(C ₆ H ₅)CHCH ₂ COC ₆ H ₄ -4-CH ₃ (80%)	346
C₁₄H₁₀O₃			
C ₆ H ₅ COC ₆ H ₄ -2-CO ₂ H	CH ₃ MgI	3-Methyl-3-phenylphthalide	416
C ₆ H ₅ COC ₆ H ₄ -2-CO ₂ H	C ₆ H ₅ MgBr	3,3-Diphenylphthalide	417,416
C₁₄H₁₁OCl			
C ₆ H ₅ COCHClC ₆ H ₅ (20 g.)	C ₆ H ₅ MgBr (34 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ CHC(C ₆ H ₅) ₂ OH (3.5 g.); C ₆ H ₅ COCH(C ₆ H ₅) ₂ (2.0 g.)*	426
C ₆ H ₅ COCHClC ₆ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHC(C ₆ H ₅) ₂ OH (< 3.5 g.); C ₆ H ₅ COCH(C ₆ H ₅) ₂ (< 2.0 g.)†	426
C ₆ H ₅ COCHClC ₆ H ₅	2-CH ₃ C ₆ H ₄ MgBr	No isolable product‡	426
C ₆ H ₅ COCHClC ₆ H ₅ (25 g.)	2-CH ₃ C ₆ H ₄ MgBr (40 g. C ₇ H ₇ Br)	(C ₆ H ₅ CO—) ₂ ; C ₆ H ₅ (2-CH ₃ C ₆ H ₄)CHCOC ₆ H ₅ ; C ₂₈ H ₂₂ O ₃ , m. 185° §	426
C ₆ H ₅ COCHClC ₆ H ₅ (20 g.)	3-CH ₃ C ₆ H ₄ MgBr (30 g. C ₇ H ₇ Br)	C ₆ H ₅ (3-CH ₃ C ₆ H ₄)CHCOC ₆ H ₅ (2 g.); C ₂₈ H ₂₂ O ₃ , m. 185°	426
4-ClC ₆ H ₄ COC ₆ H ₄ -4-CH ₃	4-CH ₃ C ₆ H ₄ MgBr	4-ClC ₆ H ₄ (4-CH ₃ C ₆ H ₄) ₂ COH (62%)	431
C₁₄H₁₁O₂N			
C ₆ H ₅ COC(=NOH)C ₆ H ₅ (22.5 g.)	CH ₃ MgI (57 g. CH ₃ I)	HO(CH ₃)(C ₆ H ₅)CC(=NOH)C ₆ H ₅	207
C ₆ H ₅ COC(=NOH)C ₆ H ₅ (22.5 g.)	C ₆ H ₅ MgBr (48 g. C ₆ H ₅ Br)	HO(C ₆ H ₅) ₂ CC(=NOH)C ₆ H ₅ (65%)	207

*Addition of ether-ketone solution to Grignard reagent solution; two hours reflux.

†Addition of Grignard reagent solution to ether-ketone solution.

‡Usual order of addition.

§Addition of Grignard reagent solution to ether-ketone solution; seven hours reflux.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₁O₂N (<i>cont.</i>)			
C ₆ H ₅ COC(=NOH)C ₆ H ₅ (22.6 g.)	1-C ₁₀ H ₇ MgBr (83 g. C ₁₀ H ₇ Br)	HO(C ₆ H ₅)(1-C ₁₀ H ₇)CC(=NOH)C ₆ H ₅ (10-15 g.)	207
C ₆ H ₅ COCONHC ₆ H ₅ (0.05 mole)	C ₆ H ₅ MgBr (<i>ca.</i> 0.15 mole)	HO(C ₆ H ₅) ₂ CCONHC ₆ H ₅ (88%)	427
C₁₄H₂₁O			
CH ₃ COC ₆ H ₄ -4-C ₆ H ₅	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ (<i>i</i> -C ₃ H ₇)(4-C ₆ H ₅ C ₆ H ₄)COH	418
C ₆ H ₅ COCH ₂ C ₆ H ₅ (18 g.)	CH ₃ MgI (30 g. CH ₃ I)	CH ₃ (C ₆ H ₅)C=CHC ₆ H ₅	350
C ₆ H ₅ COCH ₂ C ₆ H ₅	CH ₃ MgI	CH ₃ (C ₆ H ₅)(C ₆ H ₅ CH ₂)COH	353
C ₆ H ₅ COCH ₂ C ₆ H ₅	C ₂ H ₅ MgI	C ₂ H ₅ (C ₆ H ₅)(C ₆ H ₅ CH ₂)COH	353
C ₆ H ₅ COCH ₂ C ₆ H ₅ (0.10 mole)	<i>n</i> -C ₃ H ₇ MgBr (0.12 g. C ₃ H ₇ Br)	C ₆ H ₅ (C ₆ H ₅ CH ₂)CHOH (9%)*	287
C ₆ H ₅ COCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr	(C ₆ H ₅ CH=) ₂ (2.5-7.4%); reduction; no addition; pinacol (traces in some exp'ts.)	217
C ₆ H ₅ COCH ₂ C ₆ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ (C ₆ H ₅) ₂ COH ("good yield")	353, 225, 449, 619
C ₆ H ₅ COCH ₂ C ₆ H ₅	(CH ₂) ₂ CHMgBr (2 equiv.)	C ₆ H ₅ [(CH ₂) ₅ CH](C ₆ H ₅ CH ₂)COH	441
C ₆ H ₅ COCH ₂ C ₆ H ₅	3-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ (C ₆ H ₅ CH ₂)(3-CH ₃ C ₆ H ₄)COH	441
C ₆ H ₅ COCH ₂ C ₆ H ₅	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	(C ₂ H ₅) ₂ N(CH ₂) ₃ (C ₆ H ₅)(C ₆ H ₅ CH ₂)COH	226
C ₆ H ₅ COCH ₂ C ₆ H ₅ (14.8 g.)	C ₆ H ₅ CH(CO ₂ MgCl)MgCl [†] (9.65 g. C ₆ H ₅ CH ₂ CO ₂ H)	C ₆ H ₅ (C ₆ H ₅ CH ₂)[HO ₂ C(C ₆ H ₅)CH]COH (14.2 g.)	442
C ₆ H ₅ COC ₆ H ₄ -4-CH ₃	H ₂ C=CHCH ₂ Br + Mg	H ₂ C=CHCH ₂ (C ₆ H ₅)(4-CH ₃ C ₆ H ₄)COH (90%, crude)	419
C ₆ H ₅ COC ₆ H ₄ -4-CH ₃	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ (C ₆ H ₅ CH ₂)(4-CH ₃ C ₆ H ₄)COH	345
C ₆ H ₅ COC ₆ H ₄ -4-CH ₃	C ₆ H ₅ C≡CMgBr	C ₆ H ₅ (4-CH ₃ C ₆ H ₄)(C ₆ H ₅ C≡C)COH (60%)	344

*From a study of the reducing properties of Grignard reagents in which yields of reduction products only are reported.

[†]In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₂O (<i>cont.</i>)			
C ₆ H ₅ COC ₆ H ₄ -4-CH ₃ (39 g.)	4-C ₂ H ₅ C ₆ H ₄ MgBr (40 g. C ₈ H ₉ Br)	C ₆ H ₅ (4-CH ₃ C ₆ H ₄)(4-C ₂ H ₅ C ₆ H ₄)COH (yielding 8 g. chloride)	382
C ₆ H ₅ COC ₆ H ₄ -4-CH ₃ (60 g.)	4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ MgBr (71 g. C ₁₀ H ₉ Br)	C ₆ H ₅ (4-CH ₃ C ₆ H ₄)(4- <i>t</i> -C ₄ H ₉ C ₆ H ₄)COH (yielding 17 g. chloride)	382
C₁₄H₁₂O₂			
C ₆ H ₅ COCH(OH)C ₆ H ₅	CH ₃ MgCl + MgCl ₂	HO(CH ₃)(C ₆ H ₅)CCH(OH)C ₆ H ₅ (65%)*	420
C ₆ H ₅ COCH(OH)C ₆ H ₅	CH ₃ MgI + (CH ₃) ₂ Mg	HO(CH ₃)(C ₆ H ₅)CCH(OH)C ₆ H ₅ (94%) [†]	420
C ₆ H ₅ COCH(OH)C ₆ H ₅	CH ₃ MgI	HO(CH ₃)(C ₆ H ₅)CCH(OH)C ₆ H ₅	429
DL-C ₆ H ₅ COCH(OH)C ₆ H ₅ (12 g.)	CH ₃ MgI (30.3 g. CH ₃ I)	DL-HO(CH ₃)(C ₆ H ₅)CCH(OH)C ₆ H ₅ (11.5 g.)	428
(-)-C ₆ H ₅ COCH(OH)C ₆ H ₅	CH ₃ MgI	(+)-HO(CH ₃)(C ₆ H ₅)CCH(OH)C ₆ H ₅	428
C ₆ H ₅ COCH(OH)C ₆ H ₅ (10 g.)	(≡CMgBr) (24 g. Mg)	HO(HC≡C)(C ₆ H ₅)CCH(OH)C ₆ H ₅ (80%)	447
C ₆ H ₅ COCH(OH)C ₆ H ₅	C ₂ H ₅ MgBr	HO(C ₂ H ₅)(C ₆ H ₅)CCH(OH)C ₆ H ₅	429
C ₆ H ₅ COCH(OH)C ₆ H ₅ (12 g.)	C ₂ H ₅ MgI	HO(C ₂ H ₅)(C ₆ H ₅)CCH(OH)C ₆ H ₅ (13 g.)	433
(-)-C ₆ H ₅ COCH(OH)C ₆ H ₅ (4.0 g.)	C ₂ H ₅ MgI (11.8 g. C ₂ H ₅ I)	(+)-HO(C ₂ H ₅)(C ₆ H ₅)CCH(OH)C ₂ H ₅ (4.3 g., crude)	428
(-)-C ₆ H ₅ COCH(OH)C ₆ H ₅	C ₆ H ₅ MgBr	(+)-HO(C ₆ H ₅) ₂ CCH(OH)C ₆ H ₅	428
C ₆ H ₅ COCH(OH)C ₆ H ₅ (106 g.)	C ₆ H ₅ CH ₂ MgCl (189 g. C ₇ H ₇ Cl)	HO(C ₆ H ₅)(C ₆ H ₅ CH ₂)CCH(OH)C ₆ H ₅ (142 g., 93%)	443
DL-C ₆ H ₅ COCH(OH)C ₆ H ₅ (10.0 g.)	2-CH ₃ C ₆ H ₄ MgBr (25.0 g. C ₇ H ₇ Br)	α-DL-HO(C ₆ H ₅)(2-CH ₃ C ₆ H ₄)CCH(OH)C ₆ H ₅ (9.8 g.)	434
D(-)-C ₆ H ₅ COCH(OH)C ₆ H ₅ (9.0 g.)	2-CH ₃ C ₆ H ₄ MgBr (32.0 g. C ₇ H ₇ Br)	α-D(+)-HO(C ₆ H ₅)(2-CH ₃ C ₆ H ₄)CCH(OH)C ₆ H ₅ (4.2 g.); DL-C ₆ H ₅ COCH(OH)C ₆ H ₅ (1.4 g.)	434
DL-C ₆ H ₅ COCH(OH)C ₆ H ₅ (10.0 g.)	3-CH ₃ C ₆ H ₄ MgBr (40.0 g. C ₇ H ₇ Br)	α-DL-HO(C ₆ H ₅)(3-CH ₃ C ₆ H ₄)CCH(OH)C ₆ H ₅ (10.1 g.)	434

*Reaction in dioxane suspension.

[†]Reaction in isoamyl ether solution.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₂O₂ (cont.)			
D(–)-C ₆ H ₅ COCH(OH)C ₆ H ₅ (4.6 g.)	3-CH ₃ C ₆ H ₄ MgBr (17.0 g. C ₇ H ₇ Br)	α-D(+)-HO(C ₆ H ₅)(3-CH ₃ C ₆ H ₄)CCH(OH)C ₆ H ₅ (4.0 g.)	434
D(–)-C ₆ H ₅ COCH(OH)C ₆ H ₅ (4.2 g.)	4-CH ₃ C ₆ H ₄ MgBr (15.0 g. C ₇ H ₇ Br)	α-D(+)-HO(C ₆ H ₅)(4-CH ₃ C ₆ H ₄)CCH(OH)C ₆ H ₅	434
C ₆ H ₅ COCH(OH)C ₆ H ₅	C ₆ H ₅ CH(CO ₂ Na)MgCl*	α,β,γ-Triphenyl-γ-hydroxybutyric acid γ-lactone ("good yield")	149
C ₆ H ₅ COCH(OH)C ₆ H ₅	2-C ₆ H ₅ C ₆ H ₄ MgI (2 ⁺ equiv.)	HO(C ₆ H ₅)(2-C ₆ H ₅ C ₆ H ₄)CCH(OH)C ₆ H ₅ (yielding 29% phenanthrene deriv. on cyclohehydr'n)	421
C ₆ H ₅ COC ₆ H ₄ -2-OCH ₃	CH ₃ MgI	CH ₃ (C ₆ H ₅)(2-CH ₃ OC ₆ H ₄)COH	432
C ₆ H ₅ COC ₆ H ₄ -2-OCH ₃	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ MgBr	C ₆ H ₅ (2-CH ₃ OC ₆ H ₄)(2-C ₂ H ₅ OCH ₂ C ₆ H ₄)COH	363
C ₆ H ₅ COC ₆ H ₄ -3-OCH ₃	CH ₃ MgI	CH ₃ (C ₆ H ₅)(3-CH ₃ OC ₆ H ₄)COH	432
C ₆ H ₅ COC ₆ H ₄ -3-OCH ₃	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ MgBr	C ₆ H ₅ (3-CH ₃ OC ₆ H ₄)(2-C ₂ H ₅ OCH ₂ C ₆ H ₄)COH	363
C ₆ H ₅ COC ₆ H ₄ -4-OCH ₃	C ₆ H ₅ MgBr	4-CH ₃ OC ₆ H ₄ (C ₆ H ₅) ₂ COH	395
C ₆ H ₅ COC ₆ H ₄ -4-OCH ₃	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ (C ₆ H ₅ CH ₂)(4-CH ₃ OC ₆ H ₄)COH	345
C ₆ H ₅ COC ₆ H ₄ -4-OCH ₃	2-CH ₃ OC ₆ H ₄ MgI	C ₆ H ₅ (2-CH ₃ OC ₆ H ₄)(4-CH ₃ OC ₆ H ₄)COH	395
C ₆ H ₅ COC ₆ H ₄ -4-OCH ₃	4-CH ₃ OC ₆ H ₄ MgI	C ₆ H ₅ (4-CH ₃ OC ₆ H ₄) ₂ COH	395
C ₆ H ₅ COC ₆ H ₄ -4-OCH ₃	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ MgBr	C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)(2-C ₂ H ₅ OCH ₂ C ₆ H ₄)COH	363
C ₆ H ₅ COC ₆ H ₄ -4-OCH ₃	4-C ₆ H ₅ C ₆ H ₄ MgBr	C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)(4-C ₆ H ₅ C ₆ H ₄)COH	373
C₁₄H₁₂O₂ClN			
2-H ₂ N-5-ClC ₆ H ₃ CO-C ₆ H ₃ -2-OH-5-CH ₃ (12 g.)	CH ₃ MgI (45 g. CH ₃ I)	2-H ₂ N-5-ClC ₆ H ₃ (2-HO-5-CH ₃ C ₆ H ₃)C≡CH ₂ (ca. 50%)	391
C₁₄H₁₂O₃			
α-Furfurylidene- <i>p</i> -methoxyacetophenone (25 g.)	C ₂ H ₅ MgBr (27 g. C ₂ H ₅ Br)	C ₂ H ₅ (α-C ₄ H ₃ O)CHCH ₂ COC ₆ H ₄ -4-OCH ₃ (20 g.)	347

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₂O₃ (cont.)			
α -Furfurylidene- <i>p</i> -methoxyacetophenone (25 g.)	<i>n</i> -C ₃ H ₇ MgBr (31 g. C ₃ H ₇ MgBr)	<i>n</i> -C ₃ H ₇ (α -C ₄ H ₃ O)CHCH ₂ COC ₆ H ₄ -4-OCH ₃ (67%)	347
C₁₄H₁₂O₄			
2,4-(HO) ₂ C ₆ H ₃ COC ₆ H ₄ -4-OCH ₃	C ₆ H ₅ MgBr	C ₆ H ₅ [2,4-(HO) ₂ C ₆ H ₃](4-CH ₃ OC ₆ H ₄)COH	392
C₁₄H₁₃ON			
2-H ₂ NC ₆ H ₄ COC ₆ H ₄ -4-CH ₃ (21 g.)	CH ₃ MgI (60 g. CH ₃ I)	CH ₃ (2-H ₂ NC ₆ H ₄)(4-CH ₃ C ₆ H ₄)COH	397
C₁₄H₁₃O₂N			
2-H ₂ NC ₆ H ₄ COC ₆ H ₄ -4-OCH ₃ (25 g.)	C ₂ H ₅ MgI (110 g. C ₂ H ₅ I)	C ₂ H ₅ (2-H ₂ NC ₆ H ₄)(4-CH ₃ OC ₆ H ₄)COH	398
2-H ₂ NC ₆ H ₄ COC ₆ H ₄ -4-CH ₃ (15 g.)	C ₆ H ₅ CH ₂ MgCl (44 ml. C ₇ H ₇ Cl)	2-H ₂ NC ₆ H ₅ (C ₆ H ₅ CH ₂)(4-CH ₃ OC ₆ H ₄)COH (18.3 g.)	398
C₁₄H₁₄O			
1-CH ₃ COC ₁₀ H ₅ -3,4-(CH ₃) ₂ (18 g.)	CH ₃ MgI	1-[HO(CH ₃) ₂ C]C ₁₀ H ₅ -3,4-(CH ₃) ₂ (yielding 14 g., 79% olefin)	334
1-CH ₃ COC ₁₀ H ₅ -3,4-(CH ₃) ₂	C ₂ H ₅ MgBr	1-[HO(CH ₃)(C ₂ H ₅)C]C ₁₀ H ₅ -3,4-(CH ₃) ₂ (yielding 80% olefin)	334
C₁₄H₁₄OCIN			
(-)-C ₆ H ₅ COCH(NH ₂ ·HCl)C ₆ H ₅ (4.5 g.)	CH ₃ MgI (15.5 g. CH ₃ I)	(+)-HO(CH ₃)(C ₆ H ₅)CCH(NH ₂)C ₆ H ₅ (2.5 g.)	422
C ₆ H ₅ COCH(NH ₂ ·HCl)C ₆ H ₅ (30 g.)	4-CH ₃ C ₆ H ₄ MgBr (145 g. C ₇ H ₇ Br)	HO(C ₆ H ₄)(4-CH ₃ C ₆ H ₄)CCH(NH ₂)C ₆ H ₅ (27 g.)	238
DL-C ₆ H ₅ COCH(NH ₂ ·HCl)C ₆ H ₅ (20 g.)	4-CH ₃ OC ₆ H ₄ MgBr (76 g. C ₇ H ₇ BrO)	DL-HO(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)CCH(NH ₂)C ₆ H ₅ (17 g.)	422
(+)-C ₆ H ₅ COCH(NH ₂ ·HCl)C ₆ H ₅ (4 g.)	4-CH ₃ OC ₆ H ₄ MgBr (15 g. C ₇ H ₇ BrO)	(-)-HO(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)CCH(NH) ₂ C ₆ H ₅ (ca. 1.3 g.)	422
C ₆ H ₅ COCH(NH ₂ ·HCl)C ₆ H ₅	1-C ₁₀ H ₇ MgBr	HO(C ₆ H ₅)(1-C ₁₀ H ₇)CCH(NH ₂)C ₆ H ₅	444

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₄OCIN (<i>cont.</i>)			
(+)-C ₆ H ₅ COCH(NH ₂ ·HCl)C ₆ H ₅ (5 g.)	1-C ₁₀ H ₇ MgBr (25 g. C ₁₀ H ₇ Br)	(-)-HO(C ₆ H ₅)(1-C ₁₀ H ₇)CCH(NH ₂)C ₆ H ₅	422
C₁₄H₁₄OS			
2-(α -Phenylbutyryl)thiophene	C ₆ H ₅ MgBr	C ₂ H ₅ (C ₆ H ₅)C=C(α -C ₄ H ₃ S)C ₆ H ₅	301
2-(α -Phenylbutyryl)thiophene	C ₆ H ₅ CH ₂ MgBr	C ₂ H ₅ (C ₆ H ₅)C=C(α -C ₄ H ₃ S)CH ₂ C ₆ H ₅	301
C₁₄H₁₄O₂			
(4-CH ₃ C ₆ H ₄ CO—) ₂ (0.1 mole)	CH ₃ MgI (0.3 mole)	[HO(CH ₃)(4-CH ₃ C ₆ H ₄)C—] ₂ , m.p. 136–137° and m.p. 134.5–135.0°; HO(CH ₃)(4-CH ₃ C ₆ H ₄)CCOC ₆ H ₄ -4-CH ₃	88
C₁₄H₁₆O₂			
2- <i>p</i> -Xyloylcyclopentanone	C ₂ H ₅ MgBr	1-Ethyl-2- <i>p</i> -xyloylcyclopentene	400
C₁₄H₁₈O			
CH ₃ COC ₆ H ₄ -4-CH(CH ₂) ₅	C ₂ H ₅ MgBr	CH ₃ [4-(CH ₂) ₅ CHC ₆ H ₄]C=CHCH ₃	423
CH ₃ COC ₆ H ₄ -4-CH(CH ₂) ₅	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ [4-(CH ₂) ₅ CHC ₆ H ₄]C=CHC ₂ H ₅	423
CH ₃ COC ₆ H ₄ -4-CH(CH ₂) ₅	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ [4-(CH ₂) ₅ CHC ₆ H ₄]C=CH- <i>n</i> -C ₃ H ₇	423
CH ₃ COC ₆ H ₄ -4-CH(CH ₂) ₅	C ₆ H ₅ MgBr	C ₆ H ₅ [4-(CH ₂) ₅ CHC ₆ H ₄]C=CH ₂	423
C₁₄H₁₈O₃			
C ₆ H ₅ COC(CH ₃) ₂ CH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₁₈ H ₃₈ O ₂ , m. 146–147°; β , β -dimethyl- γ , γ -diphenyl- γ -butyrolactone (?)	665
C₁₄H₁₈O₄			
4-CH ₃ OC ₆ H ₄ COCH ₂ CH(CH ₃)CO ₂ C ₂ H ₅ (25 g.)	CH ₃ MgI (7.5 ml. CH ₃ I)	HO(CH ₃)(4-CH ₃ OC ₆ H ₄)CCH ₂ CH(CH ₃)CO ₂ C ₂ H ₅ (15 g.); corresponding lactone (5 g.)	436

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₂₀O			
CH ₃ CO(CH ₂) ₂ CH(CH ₃)C ₆ H ₃ -2,4-(CH ₃) ₂	CH ₃ MgI	HO(CH ₃) ₂ C(CH ₂) ₂ CH(CH ₃)C ₆ H ₃ -2,4-(CH ₃) ₂ (87%)	448
CH ₃ CO(CH ₂) ₂ CH(CH ₃)C ₆ H ₃ -2,5-(CH ₃) ₂	CH ₃ MgI	HO(CH ₃) ₂ C(CH ₂) ₂ CH(CH ₃)C ₆ H ₃ -2,5-(CH ₃) ₂ (85%)	448
<i>t</i> -C ₄ H ₉ COC ₆ H ₄ -2,4,6-(CH ₃) ₃ (21 g.)	CH ₃ MgI	No isolable product; recovered ketone (17 g.)	424
C ₆ H ₅ COC(C ₂ H ₅) ₃	CH ₃ MgI	CH ₃ (C ₆ H ₅)[C ₂ H ₅] ₃ C]COH (85%)	234
C ₆ H ₅ COC(C ₂ H ₅) ₃	C ₆ H ₅ MgBr	(C ₂ H ₅) ₃ C(C ₆ H ₅) ₂ COH *	234
C₁₅H₁₀O			
C ₆ H ₅ COC≡CC ₆ H ₅ (0.5 g.)	<i>t</i> -C ₄ H ₉ MgCl (2.0 g. C ₄ H ₉ Cl)	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)(C ₆ H ₅ C≡C)COH ("poor yield")	310
C ₆ H ₅ COC≡CC ₆ H ₅ (13.8 g.)	C ₆ H ₅ MgBr (17.5 g. C ₆ H ₅ Br)	C ₆ H ₅ C≡C(C ₆ H ₅) ₂ COH (15.4 g., 81%)	663, 111
C ₆ H ₅ COC≡CC ₆ H ₅ (2.0 g.)	1-C ₁₀ H ₇ MgBr (2.0 g. C ₁₀ H ₇ Br)	C ₆ H ₅ (C ₆ H ₅ C≡C)(1-C ₁₀ H ₇)COH (2-5 g.)	65
C ₆ H ₅ COC≡CC ₆ H ₅	C ₆ H ₅ C≡CMgBr	C ₆ H ₅ (C ₆ H ₅ C≡C) ₂ COH (43%)	367
C₁₅H₁₀OS			
3-Benzoylthianaphthene (3.0 g.)	C ₆ H ₅ CH ₂ MgCl (3.5 g. C ₇ H ₇ Cl)	1,2-Diphenyl-1-(3-thianaphthenyl)ethene (90%)	485
C₁₅H₁₀O₂			
2-Benzoylbenzofuran (8.12 g.)	C ₆ H ₅ MgBr (0.05 mole)	<i>α</i> -(2-Benzofuryl)benzhydrol (8.9 g.)	451
Benzylideneacetophenone oxide (35 g.)	C ₂ H ₅ MgBr (5 equiv.)	C ₆ H ₅ (C ₂ H ₅) ₂ COH (17 g., 66%); gum	430
Benzylideneacetophenone oxide	C ₆ H ₅ MgBr (5 equiv.)	(C ₆ H ₅) ₃ COH (<i>ca.</i> 70%); gum	430
Benzylideneacetophenone oxide (34 g.)	C ₆ H ₅ MgBr (47 g. C ₆ H ₅ Br)	1,1,3-Triphenyl-2,3-epoxy-1-propanol (22 g.) recovered ketone; unidentified products	430

*Distillation of product at ordinary pressure yields (C₆H₅)₂CO + C₇H₁₄.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₀O₂Br₂			
(C ₆ H ₅ CO) ₂ CBr ₂ (85 g.)	C ₆ H ₅ MgBr (140 g. C ₆ H ₅ Br)	HO(C ₆ H ₅) ₂ CCHBrCOC ₆ H ₅	430
(C ₆ H ₅ CO) ₂ CBr ₂	C ₆ H ₅ C≡CMgBr	HO(C ₆ H ₅)(C ₆ H ₅ C≡C)CCHBrCOC ₆ H ₅	437
C₁₅H₁₀O₃			
(C ₆ H ₅ CO) ₂ CO (14.5 g.)	C ₆ H ₅ MgBr (11.0 g. Mg)	(C ₆ H ₅) ₃ COH (9.8 g., 62%); C ₆ H ₅ COCH(OH)C ₆ H ₅	450
(C ₆ H ₅ CO) ₂ CO (14.3 g.)	C ₆ H ₅ MgBr (1.82 g. Mg)	C ₆ H ₅ COCH(O ₂ CC ₆ H ₅)C ₆ H ₅	450
C₁₅H₁₁OBr			
4-BrC ₆ H ₄ COCH=CHC ₆ H ₅	(CH ₂) ₄ CHMgBr	4-BrC ₆ H ₄ COCH ₂ CH(C ₆ H ₅)CH(CH ₂) ₄ (48%)	452
4-BrC ₆ H ₄ COCH=CHC ₆ H ₅ (34 g.)	4-BrC ₆ H ₄ MgBr (42 g. C ₆ H ₄ Br ₂)	4-BrC ₆ H ₄ COCH ₂ CH(C ₆ H ₅)C ₆ H ₄ -4-Br (18 g.)	453
C ₆ H ₅ COCBr=CHC ₆ H ₅ (28 g.)	C ₆ H ₅ MgBr (33 g. C ₆ H ₅ Br)	C ₆ H ₅ COCHBrCH(C ₆ H ₅) ₂ (35 g.)	275
C ₆ H ₅ COCBr=CHC ₆ H ₅ (40.0 g.)	4-CH ₃ C ₆ H ₄ MgBr (48.5 g. C ₇ H ₇ Br)	C ₆ H ₅ COCHBrCH(C ₆ H ₅)C ₆ H ₄ -4-CH ₃ (91%)	603
C₁₅H₁₁OCl			
4-ClC ₆ H ₄ COCH=CHC ₆ H ₅ (60 g.)	C ₆ H ₅ MgBr (47 g. C ₆ H ₅ Br)	4-ClC ₆ H ₄ COCH ₂ CH(C ₆ H ₅) ₂ (53 g.)	453
C₁₅H₁₁O₂Br			
(C ₆ H ₅ CO) ₂ CHBr (12.5 g.)	C ₆ H ₅ MgBr (1.0 g. Mg)	(C ₆ H ₅ CO) ₂ CH ₂ (9.0 g.)	437
(C ₆ H ₅ CO) ₂ CHBr (12.5 g.)	C ₆ H ₅ MgBr (2.5 g. Mg)	C ₆ H ₅ COCH ₂ C(C ₆ H ₅) ₂ OH (10.5 g.)	437
C₁₅H₁₁O₂Cl			
1-Benzoyl-2-o-chlorophenyl-1,2-epoxyethane (15.0 g.)	C ₆ H ₅ MgBr (2.82 g. Mg)	1,1-Diphenyl-2,3-epoxy-3-o-chlorophenyl-1-propanol (13.5 g.); recovered ketone (2.0 g.)	647

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₂O			
C ₆ H ₅ COCH=CHC ₆ H ₅ (0.19 mole)	CH ₃ MgBr (0.26 mole)	C ₆ H ₅ COCH ₂ CH(CH ₃)C ₆ H ₅ (54.9–56.1%); CH ₃ -(C ₆ H ₅)CH(C ₆ H ₅ CO)CHC(OH)(C ₆ H ₅)CH=CHC ₆ H ₅ (37.1–39.0%)	611
C ₆ H ₅ COCH=CHC ₆ H ₅	CH ₃ MgI	CH ₃ (C ₆ H ₅)(C ₆ H ₅ CH=CH)COH (chief product); C ₆ H ₅ COCH ₂ CH(CH ₃)C ₆ H ₅	108
C ₆ H ₅ COCH=CHC ₆ H ₅ (105 g.)	C ₂ H ₅ MgBr (58 g. C ₂ H ₅ Br)	C ₆ H ₅ COCH ₂ CH(C ₂ H ₅)C ₆ H ₅ (70 g.)	449, 111, 147, 464
C ₆ H ₅ COCH=CHC ₆ H ₅	C ₂ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH(C ₂ H ₅)C ₆ H ₅ (ca. 60%); HQ(C ₂ H ₅)(C ₆ H ₅)CCH=CHC ₆ H ₅ (ca. 40%)	611
C ₆ H ₅ COCH=CHC ₆ H ₅ (30 g., 0.205 mole)	C ₂ H ₅ MgBr (0.292 mole)	C ₆ H ₅ COCH ₂ CH(C ₂ H ₅)C ₆ H ₅ (17.5 g.); C ₂ H ₅ (C ₆ H ₅)(C ₆ H ₅ CH=CH)COH (13.5 g.)*	454
C ₆ H ₅ COCH=CHC ₆ H ₅	H ₂ C=CHCH ₂ Br + Mg	H ₂ C=CHCH ₂ (C ₆ H ₅)(C ₆ H ₅ CH=CH)COH (18.7%)	599
C ₆ H ₅ COCH=CHC ₆ H ₅	C ₆ H ₅ MgBr (2 equiv.).	(C ₆ H ₅) ₂ C=CH(C ₆ H ₅) ₂ COH; [(C ₆ H ₅) ₂ C=] ₂ C	455
C ₆ H ₅ COCH=CHC ₆ H ₅ (50 g.)	C ₆ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅) ₂ (58.5 g., 85.2%); C ₆ H ₅ CH=CH(C ₆ H ₅) ₂ COH (3.6%)	111, 147, 449, 464, 569, 611
C ₆ H ₅ COCH=CHC ₆ H ₅	(CH ₂) ₅ CHMgBr (excess)	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)CH(CH ₂) ₅ (ca. 95%)	278
C ₆ H ₅ COCH=CHC ₆ H ₅ (80 g.)	4-CH ₃ C ₆ H ₄ MgBr (80 g. C ₇ H ₇ Br)	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)C ₆ H ₄ -4-CH ₃	449
C ₆ H ₅ COCH=CHC ₆ H ₅ (105 g.)	4-CH ₃ OC ₆ H ₄ MgBr (120 g. C ₇ H ₇ BrO)	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)C ₆ H ₄ -4-OCH ₃	449
C ₆ H ₅ COCH=CHC ₆ H ₅	4-(CH ₃) ₂ NC ₆ H ₄ MgI	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)C ₆ H ₄ -4-N(CH ₃) ₂ (71%)	465
C ₆ H ₅ COCH=CHC ₆ H ₅	1-C ₁₀ H ₇ MgBr	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)-1-C ₁₀ H ₇	275
C₁₅H₁₂OBr₂			
C ₆ H ₅ COCHBrCHBrC ₆ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ COCHBrCH(C ₆ H ₅) ₂ ; C ₆ H ₅ COCH ₂ CH(C ₆ H ₅) ₂	275
C ₆ H ₅ COCHBrCHBrC ₆ H ₅	1-C ₁₀ H ₇ MgBr	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)-1-C ₁₀ H ₇	275

*Reaction at -70°; similar results at 30°.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₅H₁₂O₂			
C ₆ H ₅ COCH=CHC ₆ H ₄ -2-OH (22.4 g.)	C ₆ H ₅ MgBr (47 g. C ₆ H ₅ Br)	2,4-Diphenyl-2-chromanol (80%)	438
C ₆ H ₅ COCH=CHC ₆ H ₄ -2-OH (5 g.)	4-CH ₃ C ₆ H ₄ MgBr (11.5 g. C ₇ H ₇ Br)	2-Phenyl-4- <i>p</i> -tolyl-2-chromanol (4 g.)	438
(C ₆ H ₅ CO) ₂ CH ₂ (10 g.)	C ₆ H ₅ MgBr (21 g. C ₆ H ₅ Br)	Recovered ketone (chiefly); C ₆ H ₅ COCH=	457
		C(C ₆ H ₅) ₂ (?) *	
(C ₆ H ₅ CO) ₂ CH ₂ (5 g.)	C ₆ H ₅ MgBr (7.5 g. C ₆ H ₅ Br)	C ₆ H ₅ COC(C ₆ H ₅) ₂ OH [†]	456
(C ₆ H ₅ CO) ₂ CH ₂ (10 g., sl. excess)	C ₆ H ₅ MgBr	Recovered ketone (9.65 g.) [‡]	450
(C ₆ H ₅ CO) ₂ CH ₂	C ₆ H ₅ MgBr (excess)	C ₆ H ₅ COCH ₂ C(C ₆ H ₅) ₂ OH (82%); CH ₃ COC ₆ H ₅ ;	450
		(C ₆ H ₅) ₂ CO [§]	
(C ₆ H ₅ CO) ₂ CH ₂ (1.45 g.)	C ₆ H ₅ MgBr (0.7 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH ₂ C(C ₆ H ₅) ₂ OH (1.25 g.) [¶]	479
(C ₆ H ₅ CO) ₂ CH ₂ (0.4 g.)	C ₆ D ₅ MgBr (0.2 g. C ₆ D ₅ Br)	C ₆ H ₅ COCH ₂ (C ₆ H ₅)(C ₆ D ₅)OH (0.3 g.) [¶]	479
(C ₆ H ₅ CO) ₂ CH ₂ (7.2 g.)	4-CH ₃ C ₆ H ₄ MgBr (25 g. C ₇ H ₇ Br)	C ₆ H ₅ COCH ₂ (C ₆ H ₅)(C ₆ H ₄ -4-CH ₃)OH (6.5-	479
		6.8 g.) [¶]	
C ₆ H ₅ COCOCH ₂ C ₆ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ COC(C ₆ H ₅) ₂ OH (89%)	466
C₁₅H₁₂O₃			
C ₆ H ₅ COC ₆ H ₄ -2-CO ₂ CH ₃	C ₆ H ₅ MgBr ("large excess")	1,3,3-Triphenyl-1-phthalanol|| (90%)	459,625
C₁₅H₁₂O₃Br₂			
(3-Br-4-CH ₃ OC ₆ H ₃) ₂ CO (6.0 g.)	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ MgBr (4.3 g. C ₉ H ₁₁ BrO)	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ (3-Br-4-CH ₃ OC ₆ H ₄) ₂ COH (5.6 g.)	467

* Addition of Grignard reagent solution to ether-ketone solution; overnight at room temperature; six hours reflux.

[†] Dropwise addition of ether-ketone solution to Grignard reagent solution; three-quarters hour on water-bath.

[‡] Addition of Grignard reagent solution to ether-ketone solution; one hour reflux.

[§] Addition of ketone to Grignard reagent solution; "prolonged" reflux.

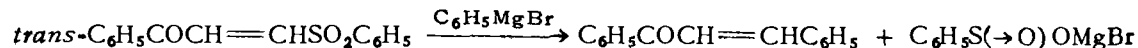
[¶] Gradual (fifteen minutes) addition of benzene-ketone solution to Grignard reagent solution at 10°; overnight standing.

^{||} Pérard (486) suggests that this product should be formulated as C₆H₅COC₆H₄-2-C(C₆H₅)₂OH.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₂O₃S <i>trans</i> -C ₆ H ₅ COCH=CHSO ₂ C ₆ H ₅ (4.08 g.)	C ₆ H ₅ MgBr (1.44 g. Mg)	HO(C ₆ H ₅) ₂ CCH=CHSO ₂ C ₆ H ₅ ; C ₆ H ₅ COCH ₂ CH(C ₆ H ₅) ₂ ; (C ₆ H ₅) ₂ SO*	653
C₁₅H₁₃O₂ CH ₃ COC(C ₆ H ₅) ₂ OH (10 g.)	CH ₃ MgBr (50 g. CH ₃ Br)	HO(CH ₃) ₂ CC(C ₆ H ₅) ₂ OH; "much" recovered ketone	292
C₁₅H₁₃O₂N C ₆ H ₅ COCON(CH ₃)C ₆ H ₅ (0.05 mole)	C ₆ H ₅ MgBr (0.25 mole)	HO(C ₆ H ₅) ₂ CCON(CH ₃)C ₆ H ₅ (81%)	427
C₁₅H₁₄O C ₆ H ₅ COCH ₂ CH ₂ C ₆ H ₅ C ₆ H ₅ COCH(CH ₃)C ₆ H ₅ (C ₆ H ₅ CH ₂) ₂ CO (21 g.) (C ₆ H ₅ CH ₂) ₂ CO (31 g.)	C ₆ H ₅ MgBr <i>t</i> -C ₄ H ₉ MgCl CH ₃ MgI 2-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ CH ₂ CH ₂ (C ₆ H ₅) ₂ COH (69%) C ₆ H ₅ [CH ₃ (C ₆ H ₅)CH]CHOH CH ₃ (C ₆ H ₅ CH ₂) ₂ COH (8 g.) Recovered ketone (20 g.); [C ₆ H ₅ CH ₂ CH(OH)—] ₂ (?)	619 648 468, 260 469
(C ₆ H ₅ CH ₂) ₂ CO	C ₆ H ₅ CH(CO ₂ Na)MgX*	C ₆ H ₅ CH(CO ₂ H)C(CH ₂ C ₆ H ₅) ₂ OH ("good yield")	200
C ₆ H ₅ CH ₂ COC ₆ H ₄ -4-CH ₃ C ₆ H ₅ CH ₂ COC ₆ H ₄ -4-CH ₃	C ₂ H ₅ MgI (3 equiv) <i>n</i> -C ₃ H ₇ MgBr	C ₂ H ₅ (C ₆ H ₅ CH ₂)(4-CH ₃ C ₆ H ₄)COH <i>n</i> -C ₃ H ₇ (C ₆ H ₅ CH ₂)(4-CH ₃ C ₆ H ₄)COH	441 441

*Apparently, one of the competing primary reactions is sulfone cleavage:



Presumably, 1,4-addition of the Grignard reagent to the unsaturated ketone formed in the cleavage accounts for the saturated ketone isolated. Bromomagnesium benzenesulfinate has been shown to react with phenylmagnesium bromide to yield phenyl sulfoxide [Kohler and Larsen (652)].

†In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₅H₁₄O (<i>cont.</i>)			
C ₆ H ₅ CH ₂ COC ₆ H ₄ -4-CH ₃	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ (C ₆ H ₅ CH ₂)(4-CH ₃ C ₆ H ₄)COH	441
C ₆ H ₅ CH ₂ COC ₆ H ₄ -4-CH ₃	3-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ CH ₂ (3-CH ₃ C ₆ H ₄)(4-CH ₃ C ₆ H ₄)COH	441
C ₆ H ₅ COC ₆ H ₄ -2-C ₂ H ₅ (21 g.)	C ₆ H ₅ MgBr (11.5 g. C ₇ H ₇ Br)	[HO(C ₆ H ₅)(2-C ₂ H ₅ C ₆ H ₄)C—] (2.5 g.); 2-C ₂ H ₅ C ₆ H ₄ (C ₆ H ₅) ₂ COH	480
(4-CH ₃ C ₆ H ₄) ₂ CO	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ (4-CH ₃ C ₆ H ₄) ₂ COH	345
(4-CH ₃ C ₆ H ₄) ₂ CO	4-CH ₃ C ₆ H ₄ MgBr	(4-CH ₃ C ₆ H ₄) ₃ COH (57%)	365
(4-CH ₃ C ₆ H ₄) ₂ CO	4-CH ₃ OC ₆ H ₄ CH ₂ MgCl	4-CH ₃ OC ₆ H ₄ CH ₂ (4-CH ₃ C ₆ H ₄) ₂ COH (75-85%)	481
(4-CH ₃ C ₆ H ₄) ₂ CO (6.5 g.)	4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ MgBr (71 g. C ₁₀ H ₁₃ Br)	4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ (4-CH ₃ C ₆ H ₄) ₂ COH (yielding 30 g. chloride)	382
C₁₅H₁₄O₂			
CH ₃ COC(C ₆ H ₅) ₂ OH	CH ₃ MgBr	HO(CH ₃) ₂ CC(C ₆ H ₅) ₂ OH	285
CH ₃ OCH ₂ COC ₆ H ₄ -2-C ₆ H ₅	CH ₃ MgI	CH ₃ (CH ₃ OCH ₂)(2-C ₆ H ₅ C ₆ H ₄)COH	16
CH ₃ OCH ₂ COC ₆ H ₄ -2-C ₆ H ₅	C ₂ H ₅ MgBr	C ₂ H ₅ (CH ₃ OCH ₂)(2-C ₆ H ₅ C ₆ H ₄)COH (yielding 53% 9-ethylphenanthrene)	470
CH ₃ COCH ₂ COC ₆ H ₄ -2-C ₆ H ₅	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ OCH ₂ (<i>n</i> -C ₃ H ₇)(2-C ₆ H ₅ C ₆ H ₄)COH (yield- ing 53% 9- <i>n</i> -propylphenanthrene)	470
CH ₃ COCH ₂ COC ₆ H ₄ -2-C ₆ H ₅	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ OCH ₂ (<i>i</i> -C ₃ H ₇)(2-C ₆ H ₅ C ₆ H ₄)COH (yield- ing 51% 9- <i>i</i> -propylphenanthrene)	470
CH ₃ OCH ₂ COC ₆ H ₄ -2-C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgCl	CH ₃ OCH ₂ (<i>n</i> -C ₄ H ₉)(2-C ₆ H ₅ C ₆ H ₄)COH (yield- ing 40% 9- <i>n</i> -butylphenanthrene)	470
CH ₃ OCH ₂ COC ₆ H ₄ -2-C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	CH ₃ OCH ₂ (C ₆ H ₅ CH ₂)(2-C ₆ H ₅ C ₆ H ₄)COH (yielding 70% 9-benzylphenanthrene)	470
C ₆ H ₅ COCH ₂ C ₆ H ₄ -4-OCH ₃ (26 g.)	C ₆ H ₅ MgBr (165 g. C ₆ H ₅ Br)	4-CH ₃ OC ₆ H ₄ CH ₂ (C ₆ H ₅) ₂ COH (yielding 170 g., 81% olefin)	180
C ₆ H ₅ COCH(OC ₆ H ₅)CH ₃	2-C ₆ H ₅ C ₆ H ₄ MgI	C ₆ H ₅ [CH ₂ (C ₆ H ₅ O)CH](2-C ₆ H ₅ C ₆ H ₄)COH	471
DL-C ₆ H ₅ COCH(OCH ₃)C ₆ H ₅ (2.7 g.)	C ₆ H ₅ MgBr (2.5 g. C ₆ H ₅ Br)	DL-HO(C ₆ H ₅) ₂ CCH(OCH ₃)C ₆ H ₅ (3.2 g.)	428

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₁₄O₂ (cont.)			
DL-C ₆ H ₅ COCH(OH)CH ₂ C ₆ H ₅ (2.0 g.)	C ₆ H ₅ MgBr (6.0 g.)	DL-HO(C ₆ H ₅) ₂ CCH(OH)CH ₂ C ₆ H ₅ (2.5 g., crude)	463
C ₆ H ₅ CH ₂ COC ₆ H ₄ -4-OCH ₃ (20 g.)	1-C ₁₀ H ₇ MgBr (25 g. C ₁₀ H ₇ Br)	C ₆ H ₅ CH=C(C ₆ H ₄ -4-OCH ₃)(1-C ₁₀ H ₇) (70%)	485
C₁₅H₁₄O₃			
C ₆ H ₅ COCH(OH)C ₆ H ₄ -4-OCH ₃	C ₂ H ₅ MgBr	β-HO(C ₂ H ₅)(C ₆ H ₅)CCH(OH)C ₆ H ₄ -4-OCH ₃	322
C ₆ H ₅ COC ₆ H ₃ -2,4-(OCH ₃) ₂	2-CH ₃ OC ₆ H ₄ MgI	C ₆ H ₅ (2-CH ₃ OC ₆ H ₄)[2,4-(CH ₃ O) ₂ C ₆ H ₃]COH	395
C ₆ H ₅ COC ₆ H ₃ -2,4-(OCH ₃) ₂ (9.2 g.)	2,4-(CH ₃ O) ₂ C ₆ H ₃ MgI (16 g. C ₈ H ₉ IO ₂)	C ₆ H ₅ [2,4-(CH ₃ O) ₂ C ₆ H ₃] ₂ COH (4.5 g.)	474
C ₆ H ₅ COC ₆ H ₃ -2,5-(OCH ₃) ₂	C ₆ H ₅ CH ₂ MgCl (2 equiv.)	C ₆ H ₅ (C ₆ H ₅ CH ₂)[2,5-(CH ₃ O) ₂ C ₆ H ₃]COH (88%)	458, 473
C ₆ H ₅ COC ₆ H ₃ -2,5-(OCH ₃) ₂ (235 g.)	C ₆ H ₅ CH(CO ₂ MgCl)MgCl* (120 g. C ₆ H ₅ CH ₂ CO ₂ H)	C ₆ H ₅ [2,5-(CH ₃ O) ₂ C ₆ H ₃][C ₆ H ₅ CH(CO ₂ H)]COH (249 g., 75%)	458
C ₆ H ₅ COC ₆ H ₃ -2,5-(OCH ₃) ₂	2,5-(CH ₃ O) ₂ C ₆ H ₃ MgI	C ₆ H ₅ [2,5-(CH ₃ O) ₂ C ₆ H ₃] ₂ COH	472
C ₆ H ₅ COC ₆ H ₃ -3,4-(OCH ₃) ₂	C ₆ H ₅ MgBr	3,4-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₂ COH	475, 395
(2-CH ₃ OC ₆ H ₄) ₂ CO	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ MgBr	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ (2-CH ₃ OC ₆ H ₄) ₂ COH	363
2-CH ₃ OC ₆ H ₄ COC ₆ H ₄ -4-OCH ₃	CH ₃ MgI	CH ₃ (2-CH ₃ OC ₆ H ₄)(4-CH ₃ OC ₆ H ₄)COH	432
2-CH ₃ OC ₆ H ₄ COC ₆ H ₄ -4-OCH ₃	2-CH ₃ C ₆ H ₄ MgBr	2-CH ₃ C ₆ H ₄ (2-CH ₃ OC ₆ H ₄)(4-CH ₃ OC ₆ H ₄)COH	363
2-CH ₃ OC ₆ H ₄ COC ₆ H ₄ -4-OCH ₃	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ MgBr	2-CH ₃ OC ₆ H ₄ (4-CH ₃ OC ₆ H ₄)(2-C ₂ H ₅ OCH ₂ C ₆ H ₄)- COH	363
3-CH ₃ OC ₆ H ₄ COC ₆ H ₄ -4-OCH ₃	CH ₃ MgI	CH ₃ (3-CH ₃ OC ₆ H ₄)(4-CH ₃ OC ₆ H ₄)COH	432
3-CH ₃ OC ₆ H ₄ COC ₆ H ₄ -4-OCH ₃	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ MgBr	3-CH ₃ OC ₆ H ₄ (4-CH ₃ OC ₆ H ₄)(2-C ₂ H ₅ OCH ₂ C ₆ H ₄)- COH	363
(4-CH ₃ OC ₆ H ₄) ₂ CO (10 g.)	4-ClC ₆ H ₄ CH ₂ MgCl (14 g. C ₇ H ₆ Cl ₂)	4-ClC ₆ H ₄ CH ₂ (4-CH ₃ OC ₆ H ₄) ₂ COH (ca. quant.)	387
(4-CH ₃ OC ₆ H ₄) ₂ CO	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ (4-CH ₃ OC ₆ H ₄) ₂ COH	345

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₄O₃ (cont.)			
(4-CH ₃ OC ₆ H ₄) ₂ CO	2-CH ₃ C ₆ H ₄ MgBr	2-CH ₃ C ₆ H ₄ (4-CH ₃ OC ₆ H ₄) ₂ COH	363
(4-CH ₃ OC ₆ H ₄) ₂ CO	C ₆ H ₅ CH=CHMgBr (+ HClO ₄)	C ₆ H ₅ CH=CH(4-CH ₃ OC ₆ H ₄) ₂ CClO ₄ (40%)	476
(4-CH ₃ OC ₆ H ₄) ₂ CO	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ MgBr	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ (4-CH ₃ OC ₆ H ₄) ₂ COH	363
(4-CH ₃ OC ₆ H ₄) ₂ CO	(C ₆ H ₅) ₂ C=CHMgBr (+ HClO ₄)	(C ₆ H ₅) ₂ C=CH(4-CH ₃ OC ₆ H ₄) ₂ CClO ₄ (50-60%)	476
C₁₅H₁₅ON			
C ₆ H ₅ COC ₆ H ₄ -3-N(CH ₃) ₂	2-(CH ₃) ₂ NC ₆ H ₄ MgI	C ₆ H ₅ [2-(CH ₃) ₂ NC ₆ H ₄][3-(CH ₃) ₂ NC ₆ H ₄]COH	394
C ₆ H ₅ COC ₆ H ₄ -4-N(CH ₃) ₂	CH ₃ MgI	C ₆ H ₅ [4-(CH ₃) ₂ NC ₆ H ₄]C=CH ₂	477
C ₆ H ₅ COC ₆ H ₄ -4-N(CH ₃) ₂ (2.00 g.)	C ₂ H ₅ MgBr (6.72 g. C ₂ H ₅ Br)	C ₂ H ₅ (C ₆ H ₅)[4-(CH ₃) ₂ NC ₆ H ₄]COH	389
C ₆ H ₅ COC ₆ H ₄ -4-N(CH ₃) ₂	C ₂ H ₅ MgI	C ₆ H ₅ [4-(CH ₃) ₂ NC ₆ H ₄]C=CHCH ₃	477
C ₆ H ₅ COC ₆ H ₄ -4-N(CH ₃) ₂	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ (C ₆ H ₅ CH ₂)[4-(CH ₃) ₂ NC ₆ H ₄]COH	477
C ₆ H ₅ COC ₆ H ₄ -4-N(CH ₃) ₂	2-(CH ₃) ₂ NC ₆ H ₄ MgI	C ₆ H ₅ [2-(CH ₃) ₂ NC ₆ H ₄][4-(CH ₃) ₂ NC ₆ H ₄]COH	394
C₁₅H₁₆OCIN			
C ₆ H ₅ COCH(NH ₂ ·HCl)CH ₂ C ₆ H ₅ (5.0 g.)	C ₆ H ₅ CH ₂ MgCl (14.5 g. C ₇ H ₇ Cl)	HO(C ₆ H ₅)(C ₆ H ₅ CH ₂)CCH(NH ₂ ·HCl)CH ₂ C ₆ H ₅ (5.5 g.)	478
C ₆ H ₅ COCH(NH ₂ ·HCl)CH ₂ C ₆ H ₅ (5.0 g.)	4-CH ₃ C ₆ H ₄ MgBr (19.7 g. C ₇ H ₇ Br)	HO(C ₆ H ₅)(4-CH ₃ C ₆ H ₄)CCH(NH ₂ ·HCl)CH ₂ C ₆ H ₅ (4.2 g.)	478
C ₆ H ₅ COCH(NH ₂ ·HCl)CH ₂ C ₆ H ₅ (5.0 g.)	1-C ₁₀ H ₇ MgBr (23.8 g. C ₁₀ H ₇ Br)	HO(C ₆ H ₅)(1-C ₁₀ H ₇)CCH(NH ₂ ·HCl)CH ₂ C ₆ H ₅ (4.3 g.)	478
C₁₅H₁₆O₃			
CH ₃ (H ₃ CO ₂ C)CHCH ₂ CO-1-C ₁₀ H ₇	CH ₃ MgI	CH ₃ (1-C ₁₀ H ₇)C=CHCH(CH ₃)CO ₂ CH ₃ (75%)	460
C₁₅H₁₆O₄			
4-CH ₃ OC ₆ H ₄ COCH(OH)C ₆ H ₄ -4-OCH ₃	C ₂ H ₅ MgI	HO(C ₂ H ₅)(4-CH ₃ OC ₆ H ₄)CCH(OH)C ₆ H ₄ -4-OCH ₃	483

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₅H₁₇O₂N			
2-Piperidinoacetylbenzofuran (8.5 g.)	C ₂ H ₅ MgBr (11.6 g. C ₂ H ₅ Br)	2-(1-Ethyl-1-hydroxy-2-piperidinoethyl)benzofuran (38%)	462
C₁₅H₁₈O			
CH ₃ (CH=CH) ₂ COC ₆ H ₂ 2,4,6-(CH ₃) ₃ (46.5 g.)	C ₆ H ₅ MgBr (39.3 g. C ₆ H ₅ Br)	CH ₃ CH=CHCH(C ₆ H ₅)CH ₂ COC ₆ H ₂ 2,4,6-(CH ₃) ₃ (51.3 g., 81%)	640
(CH ₂) ₅ CHCOCH=CHC ₆ H ₅	C ₂ H ₅ MgBr	(CH ₂) ₅ CHCOCH ₂ CH(C ₂ H ₅)C ₆ H ₅	278
(CH ₂) ₅ CHCOCH=CHC ₆ H ₅	C ₆ H ₅ MgBr	(CH ₂) ₅ CHCOCH ₂ CH(C ₆ H ₅) ₂ ; (CH ₂) ₅ CH(C ₆ H ₅)(C ₆ H ₅ CH=CH)COH (trace)	278
C₁₅H₂₀O₂			
<i>t</i> -C ₄ H ₉ COCOC ₆ H ₂ 2,4,6-(CH ₃) ₃ (8 g.)	CH ₃ MgI (8.5 g. CH ₃ I)	HO(CH ₃)(<i>t</i> -C ₄ H ₉)CCOC ₆ H ₂ 2,4,6-(CH ₃) ₃ (4 g.); <i>t</i> -C ₄ H ₉ COC(OH)(CH ₃)C ₆ H ₂ 2,4,6-(CH ₃) ₃ (1.5 g.)	424
C₁₅H₂₀O₃			
CH ₃ COCH(O ₂ CC ₆ H ₅)- <i>n</i> -C ₅ H ₁₁ (13.2 g.)	CH ₆ MgBr (10 g. Mg)	C ₆ H ₅ (CH ₃) ₂ COH (3 g.); HO(CH ₃) ₂ CCH(OH)- <i>n</i> -C ₅ H ₁₁ (6 g.)	295
C₁₅H₂₂O			
CH ₃ COCH ₂ CH(<i>i</i> -C ₅ H ₁₁)C ₆ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>i</i> -C ₅ H ₁₁)[<i>i</i> -C ₅ H ₁₁ (C ₆ H ₅)CHCH ₂]COH (?) (15-18%)	277
C₁₆H₁₀O₂Br₂			
(4-BrC ₆ H ₄ COCH=) ₂	C ₆ H ₅ MgBr	4-BrC ₆ H ₄ COCH ₂ CH(C ₆ H ₅)COC ₆ H ₄ -4-Br (53%)	488
C₁₂H₁₂O			
2-Acetophenanthrene	CH ₃ MgI	2-(2-Phenanthryl)-2-propanol (80%, crude)	489

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₆H₁₂O₂			
(C ₆ H ₅ COCH=) ₂	C ₆ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)COC ₆ H ₅ (60-65%)	488
(C ₆ H ₅ COCH=) ₂ (4.0 g.)	C ₆ H ₅ MgBr (10 ml. C ₆ H ₅ Br [+ I (9.0 g.)])	<i>cis</i> -C ₆ H ₅ COCH=C(C ₆ H ₅)COC ₆ H ₅ (0.65 g., 12.3%)	641
(C ₆ H ₅ COCH=) ₂ (4.75 g.)	C ₆ H ₅ MgBr (3.00 g. Mg) [+ I]	Tetraphenylfuran (2.1 g., 38%)	641
C₁₆H₁₂O₃			
C ₆ H ₅ COCH=CHC ₆ H ₃ =3,4=O ₂ CH ₂ (120 g.)	CH ₃ MgI (70 g. CH ₃ I)	C ₆ H ₅ COCH ₂ CH(CH ₃)C ₆ H ₃ =3,4=O ₂ CH ₂ (50 g.)	449
C ₆ H ₅ COCH=CHC ₆ H ₃ =3,4=O ₂ CH ₂ (126 g.)	C ₂ H ₅ MgBr (55 g. C ₂ H ₅ Br)	C ₆ H ₅ COCH ₂ CH(C ₂ H ₅)C ₆ H ₃ =3,4=O ₂ CH ₂	449
C ₆ H ₅ COCH=CHC ₆ H ₃ =3,4=O ₂ CH ₂ (126 g.)	C ₆ H ₅ MgBr (100 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)C ₆ H ₃ =3,4=O ₂ CH ₂	449
C₁₆H₁₄O			
C ₆ H ₅ COC(CH ₃)=CHC ₆ H ₅	CH ₃ MgI	1-Phenyl-2,3-dimethylindene (68-75%)*	490
C ₆ H ₅ COC(CH ₃)=CHC ₆ H ₅	CH ₃ MgI	CH ₃ (C ₆ H ₅)[C ₆ H ₅ CH=C(CH ₃)]COH (91%) [†]	490
C ₆ H ₅ COC(CH ₃)=CHC ₆ H ₅	C ₂ H ₅ MgBr (excess)	C ₆ H ₅ COCH(CH ₃)CH(C ₂ H ₅)C ₆ H ₅	147
C ₆ H ₅ COC(CH ₃)=CHC ₆ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ COCH(CH ₃)CH(C ₆ H ₅) ₂	569
C ₆ H ₅ COCH=C(CH ₃)C ₆ H ₅ (20 g.)	C ₂ H ₅ MgBr	C ₆ H ₅ COCH ₂ C(CH ₃)(C ₂ H ₅)C ₆ H ₅ (10 g.)	111
C ₆ H ₅ COCH=C(CH ₃)C ₆ H ₅ (20 g.)	C ₆ H ₅ MgBr	C ₆ H ₅ COCH ₂ C(C ₆ H ₅) ₂ CH ₃ (10.1 g.)	111
C ₆ H ₅ COCH=C(CH ₃)C ₆ H ₅	C ₆ H ₅ CH(CO ₂ Na)MgCl [‡]	C ₆ H ₅ COCH ₂ C(CH ₃)(C ₆ H ₅)CH(CO ₂ H)C ₆ H ₅	149

*Decomposition of the addition intermediate with iced dilute hydrochloric acid. The substituent numbering of the product is that of Patterson and Capell, "The Ring Index," Rheinhold Publishing Corp., New York City, 1940, p. 134, 876, rather than that of the article cited.

[†]Decomposition of the addition intermediate with iced aqueous ammonium chloride.

[‡]In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₆H₁₄O₂			
(C ₆ H ₅ CO) ₂ CHCH ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ COH; C ₂ H ₅ COC ₆ H ₅	450
C ₆ H ₅ COCH=CHC ₆ H ₄ -4-OCH ₃ (45.0 g.)	C ₂ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ (47.5 g.); C ₂ H ₅ (C ₆ H ₅)(4-CH ₃ OC ₆ H ₄ CH=CH)COH (yielding 0.35 g. anisic acid)	111
C ₆ H ₅ COCH=CHC ₆ H ₄ -4-OCH ₃ (50.0 g.)	C ₆ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)C ₆ H ₄ -4-OCH ₃ (63.5 g.); 4-CH ₃ OC ₆ H ₄ CH=CH(C ₆ H ₅) ₂ COH (yielding 1.1 g. anisic acid)	111
4-CH ₃ OC ₆ H ₄ COCH=CHC ₆ H ₅ (30.0 g.)	C ₂ H ₅ MgBr	4-CH ₃ OC ₆ H ₄ COCH ₂ CH(C ₂ H ₅)C ₆ H ₅ (32.0 g.); carbinol (trace)	111
4-CH ₃ OC ₆ H ₄ COCH=CHC ₆ H ₅ (25.0 g.)	C ₆ H ₅ MgBr	4-CH ₃ OC ₆ H ₄ COCH ₂ CH(C ₆ H ₅) ₂ (32.0); carbinol (trace)	111
4-CH ₃ OC ₆ H ₄ COCH=CHC ₆ H ₄ -2-OH	C ₆ H ₅ MgBr	2- <i>p</i> -Tolyl-4-phenyl-2-chromanol	438
C₁₆H₁₄O₃			
C ₆ H ₅ COC ₆ H ₄ -2-CO ₂ C ₂ H ₅ (52 g.)	CH ₃ MgI (14.3 ml. CH ₃ I)	H ₂ C=C(C ₆ H ₅)C ₆ H ₄ -2-CO ₂ H (11-15 g.); 3-methyl-3-phenylphthalide (7-15 g.)	480
Benzylidene- <i>p</i> -methoxyacetophenone oxide (5 g.)	C ₆ H ₅ MgBr (10.5 g. C ₆ H ₅ Br)	HO(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)CCH(C ₆ H ₅)CH(OH)- C ₆ H ₅ (3 g.)	492
Benzylidene- <i>p</i> -methoxyacetophenone oxide (15.0 g.)	C ₆ H ₅ MgBr (1 equiv.)	HO(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)CCH(OH)CH(C ₆ H ₅) ₂ (12.0 g.); recovered ketone (7.5 g.)*	649
Benzylidene- <i>p</i> -methoxyacetophenone oxide (15.0 g.)	C ₆ H ₅ MgBr (4 equiv.)	HO(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)CCH(OH)CH(C ₆ H ₅) ₂ (23.5 g.) [†]	649
C ₆ H ₅ COCH ₂ COC ₆ H ₄ -4-OCH ₃ (25 g.)	C ₆ H ₅ MgBr (4 equiv.)	HO(C ₆ H ₅) ₂ CCH ₂ COC ₆ H ₄ -4-OCH ₃ (ca. 7 g.); C ₆ H ₅ COCH ₂ C(OH)(C ₆ H ₅)C ₆ H ₄ -4-OCH ₃ (ca. 7 g.)	649

*Inverse addition at -15°; half-hour stirring.

[†]Normal addition; one-hour reflux.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₆H₁₄O₃Cl₂			
2-CH ₃ O-3,5-Cl ₂ C ₆ H ₂ COCH(OC ₆ H ₅)CH ₃ (3.25 g.)	2-C ₆ H ₅ C ₆ H ₄ MgI (3.5 g. C ₁₂ H ₉ I)	2-CH ₃ O-3,5-Cl ₂ C ₆ H ₂ [CH ₃ (C ₆ H ₅ O)CH] (2-C ₆ H ₅ C ₆ H ₄)COH (1.55 g., crude)	257
C₁₆H₁₄O₄			
(4-CH ₃ OC ₆ H ₄ CO—) ₂	4-ClC ₆ H ₄ MgBr	[HO(4-ClC ₆ H ₄)(4-CH ₃ OC ₆ H ₄)C—] ₂ (48%)	415
(4-CH ₃ OC ₆ H ₄ CO—) ₂	4-CH ₃ C ₆ H ₄ MgBr	[HO(4-CH ₃ C ₆ H ₄)(4-CH ₃ OC ₆ H ₄)C—] ₂ (46%)	415
C₁₆H₁₅OBr			
4-BrC ₆ H ₄ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (10 g.)	C ₆ H ₅ MgBr + Mg (0.5 g. C ₆ H ₅ Br + 1.0 g. Mg)	[2,4,6-(CH ₃) ₃ C ₆ H ₂ COC ₆ H ₄ -4—] ₂ (2 g.)	342
4-BrC ₆ H ₄ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	C ₂₂ H ₂₁ BrO (?)*, m.p. 121° (17 g., 43%); C ₂₂ H ₂₁ BrO ₂ , m.p. 131°	491
4-BrC ₆ H ₄ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	1-C ₁₀ H ₇ MgBr	C ₂₆ H ₂₃ BrO (?), m.p. 195° (chief product); C ₂₆ H ₂₃ BrO (?), m.p. 143°	491
C₁₆H₁₅O₃Cl			
4-CH ₃ OC ₆ H ₄ COCHClC ₆ H ₄ -4-OCH ₃ (170 g.)	C ₂ H ₅ MgBr (138 g. C ₂ H ₅ Br)	(4-CH ₃ OC ₆ H ₄) ₂ CHC(C ₂ H ₅) ₂ OH (72 g.)	404
C₁₆H₁₆O			
<i>i</i> -C ₃ H ₇ COC ₆ H ₄ -4-C ₆ H ₅	CH ₃ MgI	HO(CH ₃)(<i>i</i> -C ₃ H ₇)(4-C ₆ H ₅ C ₆ H ₄)COH	418
C ₆ H ₅ COCH(C ₂ H ₅)C ₆ H ₅	H ₂ C=CHCH ₂ MgX	H ₂ C=CHCH ₂ (C ₆ H ₅)[C ₂ H ₅ (C ₆ H ₅)CH]COH	461
C ₆ H ₅ COCH(C ₂ H ₅)C ₆ H ₅	<i>n</i> -C ₃ H ₇ MgX	<i>n</i> -C ₃ H ₇ (C ₆ H ₅)[C ₂ H ₅ (C ₆ H ₅)CH]COH	461
C ₆ H ₅ COCH(C ₂ H ₅)C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgX	<i>n</i> -C ₄ H ₉ (C ₆ H ₅)[C ₂ H ₅ (C ₆ H ₅)CH]COH	461

*It appears possible that the product actually isolated is 4-bromo-2'-mesitoylbiphenyl (C₂₂H₁₉BrO); either the enolate formed by 1,4-addition of the Grignard reagent to the hindered ketone or its hydrolysis product would be susceptible to atmospheric oxidation.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₁₆O (<i>cont.</i>)			
C ₆ H ₅ COCH(C ₂ H ₅)C ₆ H ₅	<i>t</i> -C ₄ H ₉ MgCl	C ₆ H ₅ [C ₂ H ₅ (C ₆ H ₅)CH]CHOH; <i>t</i> -C ₄ H ₉ (C ₆ H ₅)[C ₂ H ₅ (C ₆ H ₅)CH]COH	648
C ₆ H ₅ COCH(C ₂ H ₅)C ₆ H ₅	<i>n</i> -C ₅ H ₁₁ MgX	<i>n</i> -C ₅ H ₁₁ (C ₆ H ₅)[C ₂ H ₅ (C ₆ H ₅)CH]COH	461
C ₆ H ₅ COCH(C ₂ H ₅)C ₆ H ₅	<i>i</i> -C ₅ H ₁₁ MgX	<i>i</i> -C ₅ H ₁₁ (C ₆ H ₅)[C ₂ H ₅ (C ₆ H ₅)CH]COH	461
C ₆ H ₅ COCH(C ₂ H ₅)C ₆ H ₅	1-C ₁₀ H ₇ MgX	C ₆ H ₅ [C ₂ H ₅ (C ₆ H ₅)CH](1-C ₁₀ H ₇)COH	461
C ₆ H ₅ COC ₆ H ₄ -2,4,6-(CH ₃) ₃	CH ₃ MgI	C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂]C≡CH ₂ (64%)	221
C ₆ H ₅ COC ₆ H ₄ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	2-C ₆ H ₅ C ₆ H ₄ COC ₆ H ₄ -2,4,6-(CH ₃) ₃ (18%)	491
C ₆ H ₅ CH ₂ COC ₆ H ₄ -4-C ₂ H ₅	C ₂ H ₅ MgX (2 equiv.)	C ₂ H ₅ (C ₆ H ₅ CH ₂)(4-C ₂ H ₅ C ₆ H ₄)COH	441
C ₆ H ₅ CH ₂ COC ₆ H ₃ -2,4-(CH ₃) ₂	C ₆ H ₅ MgBr	C ₆ H ₅ (C ₆ H ₅ CH ₂)[2,4-(CH ₃) ₂ C ₆ H ₃]COH	441
C ₆ H ₅ CH ₂ COC ₆ H ₃ -2,4-(CH ₃) ₂	3-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ (3-CH ₃ C ₆ H ₄)[2,4-(CH ₃) ₂ C ₆ H ₃]COH	441
4-CH ₃ C ₆ H ₄ COCH ₂ C ₆ H ₄ -4-CH ₃ (3 g.)	4-CH ₃ C ₆ H ₄ MgBr (7.5 g. C ₇ H ₇ Br)	(4-CH ₃ C ₆ H ₄) ₂ C≡CHC ₆ H ₄ -4-CH ₃	503
4-CH ₃ C ₆ H ₄ COC ₆ H ₄ -4-C ₂ H ₅ (63 g.)	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ MgBr (100 g. C ₉ H ₁₁ Br)	4-CH ₃ C ₆ H ₄ (4-C ₂ H ₅ C ₆ H ₄)(4- <i>i</i> -C ₃ H ₇ C ₆ H ₄)COH (yielding 15 g. chloride)	382
C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂]C≡CO	(CH ₂) ₅ CHMgCl	C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂]C≡CHOH (80%)	501
C₁₆H₁₆O₂			
C ₆ H ₅ COCH ₂ C ₆ H ₄ -4-OC ₂ H ₅	4-CH ₃ OC ₆ H ₄ MgBr	C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)(4-C ₂ H ₅ OC ₆ H ₄ CH ₂)COH	497
C ₆ H ₅ COCH(OC ₆ H ₅)C ₂ H ₅	2-C ₆ H ₅ C ₆ H ₄ MgI	C ₆ H ₅ (2-C ₆ H ₅ C ₆ H ₄)[C ₂ H ₅ (C ₆ H ₅ O)CH]COH (47%)	471
C₁₆H₁₆O₃			
H ₃ CO ₂ C(CH ₂) ₂ CO-2-C ₁₀ H ₆ -6-CH ₃ (26 g.)	CH ₃ MgI (21.5 g. CH ₃ I)	CH ₃ (6-CH ₃ C ₁₀ H ₆ -2-)C≡CHCH ₂ CO ₂ H (22 g.)	330
H ₃ CO ₂ C(CH ₂) ₂ CO-2-C ₁₀ H ₆ -6-CH ₃	C ₂ H ₅ MgI	C ₂ H ₅ (6-CH ₃ C ₁₀ H ₆ -2-)C≡CHCH ₂ CO ₂ H	493
C ₆ H ₅ COCH(OH)CH(OCH ₃)C ₆ H ₅	C ₆ H ₅ MgBr (excess)	HO(C ₆ H ₅) ₂ CCH(OH)CH(OCH ₃)C ₆ H ₅ (<i>ca.</i> quant.)	430

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₁₆O₃ (cont.)			
H ₅ C ₂ O ₂ C(CH ₂) ₂ CO-2-C ₁₀ H ₇ (31 g.)	CH ₃ MgI (18 g. CH ₃ I)	CH ₃ (2-C ₁₀ H ₇)C=CHCO ₂ H (24 g.); γ-hydroxy-γ-2-naphthylvaleric acid γ-lactone	482
C₁₆H₁₆O₄			
C ₆ H ₅ COC ₆ H ₄ -2,3,4-(OCH ₃) ₃ (4.0 g.)	C ₆ H ₅ MgBr (3.5 g. C ₆ H ₅ Br)	2,3,4-(CH ₃ O) ₃ C ₆ H ₂ (C ₆ H ₅) ₂ COH	474
C ₆ H ₅ COC ₆ H ₂ -2,4,6-(OCH ₃) ₃ (3.0 g.)	C ₆ H ₅ MgBr (3.6 g. C ₆ H ₅ Br)	2,4,6-(CH ₃ O) ₃ C ₆ H ₂ (C ₆ H ₅) ₂ COH	474
4-CH ₃ OC ₆ H ₄ COCH(OH)C ₆ H ₄ -4-OCH ₃	CH ₃ MgI (5 equiv.)	β-HO(CH ₃)(4-CH ₃ OC ₆ H ₄)CCH(OH)C ₆ H ₄ -4-OCH ₃	322
4-CH ₃ OC ₆ H ₄ COCH(OH)C ₆ H ₄ -4-OCH ₃	C ₂ H ₅ MgBr	β-HO(C ₂ H ₅)(4-CH ₃ OC ₆ H ₄)CCH(OH)C ₆ H ₄ -4-OCH ₃	322
4-CH ₃ OC ₆ H ₄ COCH(OH)C ₆ H ₄ -4-OCH ₃ (27 g.)	C ₆ H ₅ MgBr (47 g. C ₆ H ₅ Br)	HO(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)CCH(OH)C ₆ H ₄ -4-OCH ₃ (25-30 g., 70-80%)	498
4-CH ₃ OC ₆ H ₄ COCH(OH)C ₆ H ₄ -4-OCH ₃	2-C ₆ H ₅ C ₆ H ₄ MgI	HO(4-CH ₃ OC ₆ H ₄)(2-C ₆ H ₅ C ₆ H ₄)CCH(OH)C ₆ H ₄ -4-OCH ₃ (yielding 28%)phenanthrene deriv. on cyclodehydr'n)	494
4-CH ₃ OC ₆ H ₄ COC ₆ H ₃ -2,3-(OCH ₃) ₂	(C ₆ H ₅) ₂ C=CHMgBr	4-CH ₃ OC ₆ H ₄ [2,3-(CH ₃ O) ₂ C ₆ H ₃][(C ₆ H ₅) ₂ C=CH]COH (60-70%)	378
CH ₃ (CH=CH) ₂ COC ₆ H-2,3,5,6-(CH ₃) ₄	C ₆ H ₅ MgBr	CH ₃ CH=CHCH(C ₆ H ₅)CH ₂ COC ₆ H-2,3,5,6-(CH ₃) ₄ (73%)	640
CH ₃ (CH=CH) ₂ COC ₆ H-2,3,5,6-(CH ₃) ₄	C ₆ H ₅ CH ₂ MgCl	CH ₃ CH=CHCH(CH ₂ C ₆ H ₅)CH ₂ COC ₆ H-2,3,5,6-(CH ₃) ₄ (88%)	640
C₁₆H₂₂O₁₁			
Pentaacetylfructose	C ₂ H ₅ MgI	C ₁₆ H ₂₂ O ₁₁ •2C ₂ H ₅ MgI (regenerating pentaacetylfructose on hydrolysis)	499

TABLE VI-XVIII (Continued)

<u>Ketonic Comp^d</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₂₄O			
C ₆ H ₅ COCH(<i>t</i> -C ₄ H ₉) ₂	CH ₃ MgBr	Addition (quant.)*	324
C ₆ H ₅ COCH(<i>t</i> -C ₄ H ₉) ₂	CH ₃ MgI	CH ₃ (C ₆ H ₅)[(<i>t</i> -C ₄ H ₉) ₂ CH]COH (61%)	324
C₁₆H₂₄O₃			
CH ₃ (C ₂ H ₅)CHCH ₂ COCH(CH ₃)C ₆ H ₃ - 3,5-(OCH ₃) ₂ (32 g.)	CH ₃ MgI (2 equiv.)	CH ₃ [CH ₃ (C ₂ H ₅)CHCH ₂][3,5-(CH ₃ O) ₂ C ₆ H ₄ CH(CH ₃)]COH (yielding 24.5 g., 81% of the 2-heptene deriv.)	504
C₁₆H₂₅ON			
(C ₂ H ₅) ₂ NCH ₂ COC ₆ H ₃ -2-CH ₃ -5- <i>i</i> -C ₃ H ₇	<i>n</i> -C ₃ H ₇ MgBr	(C ₂ H ₅) ₂ NCH ₂ (2-CH ₃ -5- <i>i</i> -C ₃ H ₇ C ₆ H ₃)CHOH	502
C₁₆H₃₀O₂			
<i>n</i> -C ₄ H ₉ COCH ₂ CH(<i>n</i> -C ₄ H ₉)CO- <i>n</i> -C ₄ H ₉ (6 g.)	C ₆ H ₅ MgBr (30 g. C ₆ H ₅ Br)	HO(<i>n</i> -C ₄ H ₉)(C ₆ H ₅)CCH ₂ CH(<i>n</i> -C ₄ H ₉)C(C ₆ H ₅)- (<i>n</i> -C ₄ H ₉)OH (0.3 g.); dehydration product (?)	495
C₁₆H₃₂O			
<i>n</i> -C ₄ H ₉ CO- <i>n</i> -C ₁₁ H ₂₃ (97 g.)	<i>n</i> -C ₁₀ H ₂₁ MgBr (212 g. C ₁₀ H ₂₁ Br)	<i>n</i> -C ₄ H ₉ (<i>n</i> -C ₁₀ H ₂₁)(<i>n</i> -C ₁₁ H ₂₃)COH	496
C₁₇H₁₂O			
C ₆ H ₅ CO-1-C ₁₀ H ₇ (0.10 mole)	<i>n</i> -C ₃ H ₇ MgBr (0.12 mole C ₃ H ₇ Br)	C ₆ H ₅ (1-C ₁₀ H ₇)CHOH (65%) [†]	287
C ₆ H ₅ CO-1-C ₁₀ H ₇	2-Thienyl-MgBr	α -C ₄ H ₃ S(C ₆ H ₅)(1-C ₁₀ H ₇)COH	272
C ₆ H ₅ CO-1-C ₁₀ H ₇ (5 g.)	C ₆ H ₅ MgBr (5 g. C ₆ H ₅ Br)	1-C ₁₀ H ₇ (C ₆ H ₅) ₂ COH (3.5 g.)	360
C ₆ H ₅ CO-1-C ₁₀ H ₇	C ₆ H ₅ C \equiv CMgBr	C ₆ H ₅ (C ₆ H ₅ C \equiv C)(1-C ₁₀ H ₇)COH	65
C ₆ H ₅ CO-1-C ₁₀ H ₇ (45 g.)	9-Phenanthryl-MgBr (50 g. C ₁₄ H ₉ Br)	C ₆ H ₅ (1-C ₁₀ H ₇)(9-C ₁₄ H ₉)COH (12 g., 14.5%)	511

* "Grignard machine" study.

[†] From a study of the reducing properties of Grignard reagents in which yields of reduction products only are reported.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₁₂O (<i>cont.</i>)			
C ₆ H ₅ CO-2-C ₁₀ H ₇	C ₆ H ₅ MgBr	2-C ₁₀ H ₇ (C ₆ H ₅) ₂ COH	505
C₁₇H₁₂OS			
4-(2-Thenoyl)biphenyl (5.5 g.)	C ₆ H ₅ CH ₂ MgCl (5.0 g.)	α -C ₄ H ₃ S(C ₆ H ₅ CH ₂)(4-C ₆ H ₅ C ₆ H ₄)COH (yielding <i>ca.</i> 7.0 g. crude ethene deriv.)	254
C₁₇H₁₂O₂			
4-(2-Furoyl)biphenyl (12 g.)	C ₆ H ₅ CH ₂ MgCl (12.5 g. C ₇ H ₇ Cl)	α -C ₄ H ₃ O(4-C ₆ H ₅ C ₆ H ₄)C=CHC ₆ H ₅ (8 g.)	485
2-C ₆ H ₅ COC ₁₀ H ₆ -6-OH	C ₆ H ₅ MgBr (excess)	6-HO-2-C ₁₀ H ₆ (C ₆ H ₅) ₂ COH (75%)	527
3-C ₆ H ₅ COC ₁₀ H ₆ -2-OH (3.7 g.)	1-C ₁₀ H ₇ MgBr (25 g. C ₁₀ H ₇ Br)	C ₆ H ₅ (1-C ₁₀ H ₇)(2-HO-3-C ₁₀ H ₆)COH (yielding 3.7 g., 67% 14-phenyl-14 <i>H</i> -dibenzo-[<i>a, i</i>]xanthene)	512
3-C ₆ H ₅ COC ₁₀ H ₆ -2-OH (3.7 g.)	1-CH ₃ C ₁₀ H ₆ -2-MgI (20 g. C ₁₁ H ₉ I)	C ₆ H ₅ (2-HO-3-C ₁₀ H ₆)(1-CH ₃ -2-C ₁₀ H ₆)COH	512
C₁₇H₁₃OBr			
4-BrC ₆ H ₄ CO(CH=CH) ₂ C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	4-BrC ₆ H ₄ COCH ₂ CH(CH ₂ C ₆ H ₅)CH=CHC ₆ H ₅	506
C₁₇H₁₄O			
C ₆ H ₅ CO(CH=CH) ₂ C ₆ H ₅	C ₂ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH(C ₂ H ₅)CH=CHC ₆ H ₅ *	507
C ₆ H ₅ CO(CH=CH) ₂ C ₆ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)CH=CHC ₆ H ₅ (73%)	507
C ₆ H ₅ CO(CH=CH) ₂ C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ COCH ₂ CH(CH ₂ C ₆ H ₅)CH=CHC ₆ H ₅ *	507
(C ₆ H ₅ CH=CH) ₂ CO (50 g.)	C ₂ H ₅ MgBr	C ₆ H ₅ CH=CHCOCH ₂ CH(C ₂ H ₅)C ₆ H ₅ (51 g.)	111
(C ₆ H ₅ CH=CH) ₂ CO	H ₂ C=CHCH ₂ Br + Mg	C ₃₇ H ₃₄ O ₂ , m.p. 89°	600
(C ₆ H ₅ CH=CH) ₂ CO (200 g.)	<i>t</i> -C ₄ H ₉ MgCl (48 g. Mg)	C ₆ H ₅ CH=CHCOCH ₂ CH(<i>t</i> -C ₄ H ₉)C ₆ H ₅ (190 g.)	276
(C ₆ H ₅ CH=CH) ₂ CO (60 g.)	C ₆ H ₅ MgBr	C ₆ H ₅ CH=CHCOCH ₂ CH(C ₆ H ₅) ₂ (57 g.)	111
(C ₆ H ₅ CH=CH) ₂ CO	C ₆ H ₅ C≡CMgBr	C ₆ H ₅ C≡C(C ₆ H ₅ CH=CH) ₂ COH (?)	367

*Reported by Bauer, *Ber.*, 38, 688-90 (1905), as the tertiary alcohol.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp^d</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₁₅OBr			
C ₆ H ₅ [2,4,6-(CH ₃) ₃ -3-BrC ₆ H] $\text{C}=\text{CO}$ (2.8 g.)	<i>i</i> -C ₄ H ₉ MgCl (excess)	C ₆ H ₅ [2,4,6-(CH ₃) ₃ -3-BrC ₆ H] $\text{C}=\text{CHOH}$ (2.3 g.)	501
C₁₇H₁₆O			
C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂] $\text{C}=\text{CO}$ (1 g.)	CH ₃ MgI (3.5 g. CH ₃ I)	C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂]CHCOCH ₃	500, 501, 530
C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂] $\text{C}=\text{CO}$ (9.5 g.)	C ₆ H ₅ MgBr (9.7 g. C ₆ H ₅ Br)	C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂]CHCOC ₆ H ₅	500
C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂] $\text{C}=\text{CO}$	(CH ₂) ₅ CHMgCl	C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂] $\text{C}=\text{CHOH}$ (80%)	501
C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂] $\text{C}=\text{CO}$ (8.0 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (12.6 g. C ₉ H ₁₁ Br)	C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂] $\text{C}=\text{C}$ [C ₆ H ₂ -2,4,6-(CH ₃) ₃]OH (8.0 g.)	530
C₁₇H₁₆O₂			
C ₆ H ₅ COCH=C(OC ₂ H ₅)C ₆ H ₅	C ₂ H ₅ MgBr†	C ₂ H ₅ (C ₆ H ₅)[C ₂ H ₅ O(C ₆ H ₅)C=CH]COH; C ₆ H ₅ COCH ₂ C(C ₂ H ₅)(OC ₂ H ₅)C ₆ H ₅ ; C ₆ H ₅ [C ₂ H ₅ O(C ₆ H ₅)C=CH]C=CHCH ₃ ; C ₃₄ H ₃₂ O ₃	147
C ₆ H ₅ COCH=C(OC ₂ H ₅)C ₆ H ₅	C ₆ H ₅ MgBr	C ₂ H ₅ O(C ₆ H ₅)C=CH(C ₆ H ₅) ₂ COH*	147
C ₆ H ₅ COCH=C(OC ₂ H ₅)C ₆ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ C=CH(C ₆ H ₅) ₂ COH; [(C ₆ H ₅) ₂ C=] ₂ C†	147
(C ₆ H ₅ CO) ₂ C(CH ₃) ₂ (5 g.)	CH ₃ MgI (6 g. CH ₃ I)	C ₆ H ₅ CO(CH ₃) ₂ CC(CH ₃)(C ₆ H ₅)OH†	457
(C ₆ H ₅ CO) ₂ C(CH ₃) ₂	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ COH (<i>ca.</i> quant.)	450
C ₆ H ₅ COCOC ₆ H ₂ -2,4,6-(CH ₃) ₃	CH ₃ MgI	HO(CH ₃)(C ₆ H ₅)CCOC ₆ H ₂ -2,4,6-(CH ₃) ₃	508
C ₆ H ₅ COCOC ₆ H ₂ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	HO(C ₆ H ₅) ₂ CCOC ₆ H ₂ -2,4,6-(CH ₃) ₃	509

* Portionwise addition of solid ketone to concentrated Grignard reagent solution.

† Portionwise addition of solid ketone to dilute Grignard reagent solution.

‡ According to Kohler and Erickson (450) this product is probably a mixture of *i*-C₃H₇COC₆H₅ and CH₃(C₆H₅)CHOH.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₁₆O₃			
4-CH ₃ OC ₆ H ₄ COCH=CHC ₆ H ₄ -4-OCH ₃	CH ₃ Mgl (3 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ CH(CH ₃)C ₆ H ₄ -4-OCH ₃ (45%)	513
4-CH ₃ OC ₆ H ₄ COCH=CHC ₆ H ₄ -4-OCH ₃	C ₂ H ₅ MgBr (3 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ CH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ (80%)	513
4-CH ₃ OC ₆ H ₄ COCH=CHC ₆ H ₄ -4-OCH ₃	<i>n</i> -C ₃ H ₇ MgBr (3 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ CH(<i>n</i> -C ₃ H ₇)C ₆ H ₄ -4-OCH ₃ (80%)	513
4-CH ₃ OC ₆ H ₄ COCH=CHC ₆ H ₄ -4-OCH ₃	<i>i</i> -C ₃ H ₇ MgBr (3 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ CH(<i>i</i> -C ₃ H ₇)C ₆ H ₄ -4-OCH ₃ (75%)	513, 514
4-CH ₃ OC ₆ H ₄ COCH=CHC ₆ H ₄ -4-OCH ₃	<i>n</i> -C ₄ H ₉ MgBr (3 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ CH(<i>n</i> -C ₄ H ₉)C ₆ H ₄ -4-OCH ₃ (70%)	513
4-CH ₃ OC ₆ H ₄ COCH=CHC ₆ H ₄ -4-OCH ₃	<i>n</i> -C ₅ H ₁₁ MgBr (3 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ CH(<i>n</i> -C ₅ H ₁₁)C ₆ H ₄ -4-OCH ₃ (75%)	513
4-CH ₃ OC ₆ H ₄ COCH=CHC ₆ H ₄ -4-OCH ₃	C ₆ H ₅ MgBr (3 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ CH(C ₆ H ₅)C ₆ H ₄ -4-OCH ₃ (75%)	513
4-CH ₃ OC ₆ H ₄ CH=CHC ₆ H ₄ -4-OCH ₃	(CH ₂) ₅ CHMgCl	4-CH ₃ OC ₆ H ₄ COCH ₂ CH[CH(CH ₂) ₅]C ₆ H ₄ -4-OCH ₃ (85%)	514
4-CH ₃ OC ₆ H ₄ CH=CHC ₆ H ₄ -4-OCH ₃	C ₆ H ₅ CH ₂ MgCl (3 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ CH(CH ₂ C ₆ H ₅)C ₆ H ₄ -4-OCH ₃ (70%)	513
4-CH ₃ OC ₆ H ₄ CH=CHC ₆ H ₄ -4-OCH ₃	4-CH ₃ OC ₆ H ₄ MgBr (3 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ CH(C ₆ H ₄ -4-OCH ₃) ₂ (70%)	513
H ₅ C ₂ O ₂ CCOCH(C ₆ H ₅) ₂ * (10 g.)	C ₆ H ₅ MgBr (excess)	(C ₆ H ₅) ₂ CHC(OH)(C ₆ H ₅)CO ₂ C ₂ H ₅ (8 g.) [†]	430
H ₅ C ₂ O ₂ CCOCH(C ₆ H ₅) ₂ *	C ₆ H ₅ MgBr ("large excess")	(C ₆ H ₅) ₂ CHC(OH)(C ₆ H ₅)CO ₂ C ₂ H ₅ ; (C ₆ H ₅) ₂ CHC(OH)(C ₆ H ₅)C(C ₆ H ₅) ₂ OH [‡]	430

* According to Kohler *et al.* (430) this is the ester actually investigated by Bardon and Ramart, *Compt. rend.*, 183, 214-6 (1926), who supposed that they were dealing with the isomeric epoxy compound.

[†] Addition of ether-ketone solution to ice-cold Grignard reagent solution. Similar inverse addition yielded 10 g. of the same product.

[‡] Addition of ketone to Grignard reagent solution; several days at room temperature or 3-4 hours reflux.

TABLE VI-XVIII (Continued)

Ketonic Comp'd	RMgX	Product(s)	Ref.
C₁₇H₁₇OBr			
C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄ -4-Br (13.0 g.)	<i>t</i> -C ₄ H ₉ MgCl (30.0 ml. C ₄ H ₉ Cl)	4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ -4-Br (6.1 g., 40%)	510
C₁₇H₁₇ON			
C ₆ H ₅ COCH=CHC ₆ H ₄ -4-N(CH ₃) ₂ 4-(2,5-Dimethyl-1-pyrrolyl)benzophenone (14 g.)	C ₆ H ₅ MgBr C ₆ H ₅ CH ₂ MgCl (15 g. C ₇ H ₇ Cl)	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)C ₆ H ₄ -4-N(CH ₃) ₂ (66%) 1,2-Diphenyl-1-[4-(2,5-dimethyl-1-pyrrolyl)-phenyl]ethylene	465 485
C₁₇H₁₇O₃N			
C ₆ H ₅ COCON(CH ₃)C ₆ H ₄ -4-OC ₂ H ₅ (20 g.)	C ₆ H ₅ MgBr (excess)	HO(C ₆ H ₅) ₂ CCON(CH ₃)C ₆ H ₄ -4-OC ₂ H ₅ (23 g., 93%)	427
C₁₇H₁₆O			
C ₆ H ₅ COCH(<i>n</i> -C ₃ H ₇)C ₆ H ₅	<i>n</i> -C ₃ H ₇ MgX	<i>n</i> -C ₃ H ₇ (C ₆ H ₅)[<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CH]COH	461
C ₆ H ₅ COCH(<i>n</i> -C ₃ H ₇)C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgX	<i>n</i> -C ₄ H ₉ (C ₆ H ₅)[<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CH]COH	461
C ₆ H ₅ COC ₆ H-2,3,4,5-(CH ₃) ₄	CH ₃ Mgl	C ₆ H ₅ [2,3,4,5-(CH ₃) ₄ C ₆ H]C=CH ₂ (42%)	221
C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄ (100 g.)	CH ₃ Mgl (198 g. CH ₃ I)	C ₆ H ₅ [2,3,5,6-(CH ₃) ₄ C ₆ H]C=CH ₂ (15 g.); dihydro- <i>o</i> -toluyldurene, <i>A</i> isomer, m.p. 123–124° (34 g.); <i>p</i> -toluyldurene (0.5 g.); {C ₆ H ₅ [2,3,5,6-(CH ₃) ₄ C ₆ H]CH} ₂ O (3 g.); <i>o</i> -toluyldurene*	228
C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄ (20 g.)	CH ₃ Mgl (39.6 g. CH ₃ I)	C ₆ H ₅ [2,3,5,6-(CH ₃) ₄ C ₆ H]C=CH ₂ (3 g., crude); dihydro- <i>o</i> -toluyldurene, <i>B</i> isomer, m.p. 103.0–103.5° (6 g.) [†]	228
C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄ (9.5 g.)	<i>i</i> -C ₃ H ₇ MgBr (0.12 mole)	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (38%)	528

* Addition of solid ketone and butyl ether to Grignard reagent solution; slow distillation of ethyl ether with addition of butyl ether; six hours under nitrogen at 130° with stirring; dilute aqueous sulfuric acid hydrolysis at 0°.

[†] Procedure as described in preceding footnote*; hydrolysis with aqueous ammonium chloride at 0°.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₁₈O (<i>cont.</i>)			
C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄	<i>s</i> -C ₄ H ₉ MgBr	4- <i>s</i> -C ₄ H ₉ C ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (63%)	528
C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄ (10 g.)	<i>t</i> -C ₄ H ₉ MgCl (28 ml. C ₄ H ₉ Cl)	4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (33%)	510
C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄	(CH ₂) ₅ CHMgCl	4-(CH ₂) ₅ CHC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (38%)	528
C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄	C ₆ H ₅ CH ₂ MgCl	4-C ₆ H ₅ CH ₂ C ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄	510
4-CH ₃ C ₆ H ₄ COCH(C ₂ H ₅)C ₆ H ₅	C ₂ H ₅ MgI	C ₂ H ₅ (4-CH ₃ C ₆ H ₄)[C ₂ H ₅ (C ₆ H ₅)CH]COH	441
4-CH ₃ C ₆ H ₄ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	CH ₃ MgI	4-CH ₃ C ₆ H ₄ [2,4,6-(CH ₃) ₃ C ₆ H ₄]C≡CH ₂	221
4-CH ₃ C ₆ H ₄ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	4-CH ₃ C ₆ H ₄ MgBr	2-Mesityl-4',5-dimethylbiphenyl; recovered ketone; unidentified oil	491
C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄ (11.9 g.)	2-Thianaphthenylmethyl-MgCl (0.0361 mole)	1-Phenyl-1-duryl-2-thianaphthenylethanol (4.27 g., 31%)	661
C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄ (11.9 g.)	3-Thianaphthenylmethyl-MgCl (0.0825 mole)	α-Duryl-β-3-thianaphthenylstyrene (3.9 g., 30%)	659
C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄	3-Methyl-2-thianaphthenyl-MgBr + Mg	{2-[2,3,5,6-(CH ₃) ₄ C ₆ H]C ₆ H ₄ —} ₂	659
C₁₇H₁₈O₂			
C ₆ H ₅ COCH ₂ C ₆ H ₄ -4-O- <i>n</i> -C ₃ H ₇ (2 parts)	4-CH ₃ OC ₆ H ₄ MgBr (7.2 parts C ₇ H ₇ BrO)	C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)(4- <i>n</i> -C ₃ H ₇ OC ₆ H ₄)COH	497
2-CH ₃ OC ₆ H ₄ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	2-C ₆ H ₅ C ₆ H ₄ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (35%)*	519
2-CH ₃ OC ₆ H ₄ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	2,6-(C ₆ H ₅) ₂ C ₆ H ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (20%)†	519
2-CH ₃ OC ₆ H ₄ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	2-CH ₃ OC ₆ H ₄ MgBr	2- <i>o</i> -CH ₃ OC ₆ H ₄ C ₆ H ₄ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (47%)†	519
2-CH ₃ OC ₆ H ₄ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (12.7 g.)	2-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂]C ₆ H ₄ MgBr (14.5 g. C ₁₆ H ₁₇ Br)	2-[2,4,6-(CH ₃) ₃ C ₆ HCO]C ₆ H ₄ C ₆ H ₄ -2-[CH ₂ C ₆ H ₂ -2,4,6-(CH ₃) ₃] (7.8 g., 33%)	642
3-CH ₃ OC ₆ H ₄ COC ₆ H ₄ -2,4,6-(CH ₃) ₃ (6.4 g.)	C ₆ H ₅ MgBr (8 g. C ₆ H ₅ Br)	2-C ₆ H ₅ -5-CH ₃ OC ₆ H ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (?) (0.5 g., crude)†	519

* Reaction at 30°.

† Addition of benzene-ketone solution to Grignard reagent solution; eight hours reflux at 60°.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₁₈O₂ (cont.)			
3-CH ₃ OC ₆ H ₄ COC ₆ H ₃ -2,4,6-(CH ₃) ₃ (5 g.)	C ₆ H ₅ CH ₂ MgCl	3-CH ₃ O-4-C ₆ H ₅ CH ₂ C ₆ H ₃ COC ₆ H ₃ -2,4,6-(CH ₃) ₃ (0.6 g., 9%)	515
4-CH ₃ OC ₆ H ₄ COC ₆ H ₃ -2,4,6-(CH ₃) ₃ (10 g.)	C ₆ H ₅ CH ₂ MgCl	2-Benzyl-4-methoxy-1,2-dihydrophenyl mesityl ketone (2.7 g., 20%)	515
C₁₇H₁₈O₃			
4-CH ₃ OC ₆ H ₄ CO(CH ₂) ₂ C ₆ H ₄ -3-OCH ₃ (21.6 g.)	<i>n</i> -C ₃ H ₇ MgI	Oily carbinol (yielding 18 g. crude olefin)	531
4-CH ₃ OC ₆ H ₄ CO(CH ₂) ₂ C ₆ H ₄ -4-OCH ₃	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CH(4-CH ₃ OC ₆ H ₄)(4-CH ₃ OC ₆ H ₄ - CH ₂ CH ₂)COH	514
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃	C ₂ H ₅ MgBr	C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)[C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)CH]- COH, two isomers (75%)	520
(4-C ₂ H ₅ OC ₆ H ₄) ₂ CO (10 g.)	C ₆ H ₅ CH ₂ MgCl (14 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ (4-C ₂ H ₅ OC ₆ H ₄) ₂ COH (<i>ca.</i> quant.)	387
C₁₇H₁₈O₄			
4-CH ₃ OC ₆ H ₄ COCH(OCH ₃)C ₆ H ₄ -4-OCH ₃	2-(<i>p</i> -ClC ₆ H ₄)C ₆ H ₄ MgI (6.94 g. C ₁₂ H ₈ ClI)	4-CH ₃ OC ₆ H ₄ [2-(<i>p</i> -ClC ₆ H ₄)C ₆ H ₄][CH ₃ O(4- CH ₃ OC ₆ H ₄)CH]COH [yielding 1 g., 13%] of 2-chloro-9,10-bis-(<i>p</i> -hydroxyphenyl)- phenanthrene]	421
C₁₇H₁₈O₅			
[2,5-(CH ₃ O) ₂ C ₆ H ₃] ₂ CO	C ₂ H ₅ MgBr	C ₂ H ₅ [2,5-(CH ₃ O) ₂ C ₆ H ₃] ₂ COH (88%)	522,473
[2,5-(CH ₃ O) ₂ C ₆ H ₃] ₂ CO	2,5-(CH ₃ O) ₂ C ₆ H ₃ MgI	[2,5-(CH ₃ O) ₂ C ₆ H ₃] ₂ COH (76%)	472
[3,4-(CH ₃ O) ₂ C ₆ H ₃] ₂ CO	CH ₃ MgI	[3,4-(CH ₃ O) ₂ C ₆ H ₃] ₂ C≡CH ₂ ("low yield")	516
C₁₇H₂₀O			
8-Benzoylcamphene	CH ₃ MgI	8-(α -Phenylvinyl)camphene	339

TABLE VI-XVIII (Continued)

Ketonic Comp'd	RMgX	Product (s)	Ref.
C₁₇H₂₀ON₂			
[2-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	2-(CH ₃) ₂ NC ₆ H ₄ MgI (excess)	[2-(CH ₃) ₂ NC ₆ H ₄] ₃ COH ("good yield")	394
[3-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	C ₆ H ₅ MgBr	C ₆ H ₅ [3-(CH ₃) ₂ NC ₆ H ₄] ₂ COH	394
[3-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	2-(CH ₃) ₂ NC ₆ H ₄ MgI	2-(CH ₃) ₂ NC ₆ H ₄ [3-(CH ₃) ₂ NC ₆ H ₄] ₂ COH	394
3-(CH ₃) ₂ NC ₆ H ₄ COC ₆ H ₄ -4-N(CH ₃) ₂	C ₆ H ₅ MgBr	C ₆ H ₅ [3-(CH ₃) ₂ NC ₆ H ₄][4-(CH ₃) ₂ NC ₆ H ₄] ₂ COH	394
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	C ₂ H ₅ MgBr (4 equiv.)	[4-(CH ₃) ₂ NC ₆ H ₄] ₂ C=CH ₂	477
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	C ₂ H ₅ MgBr (4 equiv.)	C ₂ H ₅ [4-(CH ₃) ₂ NC ₆ H ₄] ₂ COH	389
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	C ₂ H ₅ MgI	[4-(CH ₃) ₂ NC ₆ H ₄] ₂ C=CHCH ₃	477
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO (13.5 g.)	<i>i</i> -C ₃ H ₇ MgI (45 g. C ₃ H ₇ I)	[4-(CH ₃) ₂ NC ₆ H ₄] ₂ C=C(CH ₃) ₂ (ca. 9 g.)	517
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	2-Thienyl-MgBr	α -C ₄ H ₃ S[4-(CH ₃) ₂ NC ₆ H ₄] ₂ COH	523
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	<i>i</i> -C ₅ H ₁₁ MgI	[4-(CH ₃) ₂ NC ₆ H ₄] ₂ C=CH- <i>i</i> -C ₃ H ₇	477
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO (0.005 mole)	C ₆ H ₅ MgBr (0.005 mole)	C ₆ H ₅ [4-(CH ₃) ₂ NC ₆ H ₄] ₂ COH (42%); recovered ketone (45%)	529
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	(CH ₂) ₅ CHMgBr	[4-(CH ₃) ₂ NC ₆ H ₄] ₂ C=C(CH ₂) ₅ ("very poor yield"; much recovered ketone)	524
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO (50 g.)	C ₆ H ₅ CH ₂ MgCl (24 ml. C ₇ H ₇ Cl)	[4-(CH ₃) ₂ NC ₆ H ₄] ₂ C=CHC ₆ H ₅ (47 g. hydrochloride)	525
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	2-CH ₃ OC ₆ H ₄ MgI	2-CH ₃ OC ₆ H ₄ [4-(CH ₃) ₂ NC ₆ H ₄] ₂ COH	526
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	3-CH ₃ OC ₆ H ₄ MgI	3-CH ₃ OC ₆ H ₄ [4-(CH ₃) ₂ NC ₆ H ₄] ₂ COH	526
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	4-CH ₃ OC ₆ H ₄ MgBr	4-CH ₃ OC ₆ H ₄ [4-(CH ₃) ₂ NC ₆ H ₄] ₂ COH	526
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	4-C ₂ H ₅ OC ₆ H ₄ MgBr	4-C ₂ H ₅ OC ₆ H ₄ [4-(CH ₃) ₂ NC ₆ H ₄] ₂ COH	526
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	4-(CH ₃) ₂ NC ₆ H ₄ MgBr	[4-(CH ₃) ₂ NC ₆ H ₄] ₃ COH	371, 417
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	2-CH ₃ C ₁₀ H ₆ -1-MgBr	2-CH ₃ -1-C ₁₀ H ₆ [4-(CH ₃) ₂ C ₆ H ₄] ₂ COH	532
[4-(CH ₃) ₂ NC ₆ H ₄] ₂ CO	4-CH ₃ C ₁₀ H ₆ -1-MgBr	4-CH ₃ -1-C ₁₀ H ₆ [4-(CH ₃) ₂ NC ₆ H ₄] ₂ COH	532
C₁₇H₂₀O₃			
CH ₃ CO(CH ₂) ₂ -2-C ₁₀ H ₄ -1,4-(OCH ₃) ₂ -3-CH ₃ (6.8 g.)	CH ₃ MgI (0.075 mole)	HO(CH ₃) ₂ C(CH ₂) ₂ -2-C ₁₀ H ₄ -1,4-(OCH ₃) ₂ -3-CH ₃ (6.6 g.)	521

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₇H₂₆O			
2-CH ₃ C ₆ H ₄ COCH(<i>t</i> -C ₄ H ₉) ₂	CH ₃ MgBr	Addition (quant.)*	324
CH ₃ COCH=CHC(CH ₃)=CHCH ₂ R [†] (450 mg.)	C ₂ H ₅ MgBr (100 mg. Mg)	HO(CH ₃)(C ₂ H ₅)CCH=CHC(CH ₃)=CHCH ₂ R [†] (143 mg.)	643
C₁₈H₁₁O₃Cl			
2-(<i>o</i> -ClC ₆ H ₄ CO)C ₁₀ H ₆ -1-CO ₂ H (6.21 g.)	CH ₃ MgBr (20 ml., 0.214 M)	3-Methyl-3- <i>o</i> -chlorophenyl-6,7-benzophthalide (4.86 g., 79%)	533
2-(<i>p</i> -ClC ₆ H ₄ CO)C ₁₀ H ₆ -1-CO ₂ H (0.029 mole)	CH ₃ MgBr (0.073 mole)	3-Methyl-3- <i>p</i> -chlorophenyl-6,7-benzophthalide (7.1 g., 80%)	534
C₁₈H₁₂O₃			
2-C ₆ H ₅ COC ₁₀ H ₆ -1-CO ₂ H	CH ₃ MgBr (3 equiv.)	3-Methyl-3-phenyl-6,7-benzophthalide (89%)	331
2-(α -C ₁₀ H ₇ CO)C ₆ H ₄ -1-CO ₂ H (13.8 g.)	CH ₃ MgBr (7.29 g. Mg)	3-Methyl-3- α -naphthylphthalide (8.0 g., 58%)	535
C₁₈H₁₄OS			
4-(5-Methyl-2-thenoyl)biphenyl (4 g.)	C ₆ H ₅ CH ₂ MgCl (3.7 g. C ₇ H ₇ Cl)	α' -CH ₃ - α -C ₄ H ₃ S(C ₆ H ₅ CH ₂)(4-C ₆ H ₄ C ₆ H ₅)COH (yielding ethene <i>ca.</i> quant.)	254
C₁₈H₁₄O₂			
1-C ₆ H ₅ COC ₁₀ H ₆ -4-OCH ₃	C ₆ H ₅ MgBr	1-(4-CH ₃ OC ₁₀ H ₆)(C ₆ H ₅) ₂ COH	537
C₁₈H₁₆O			
C ₆ H ₅ C \equiv CCOC ₆ H ₂ -2,4,6-(CH ₃) ₃ (1 g.)	CH ₃ MgI (3 ml. CH ₃ I)	CH ₃ (C ₆ H ₅)C=CHCOC ₆ H ₂ -2,4,6-(CH ₃) ₃ (0.78 g., 73%)	393
C ₆ H ₅ C \equiv CCOC ₆ H ₂ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ C=CHCOC ₆ H ₂ -2,4,6-(CH ₃) ₃	393

* "Grignard machine" study.

[†] R = 1,3,3-trimethyl-2-cyclohexen-1-yl.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₈H₁₆O (<i>cont.</i>)			
C ₆ H ₅ C≡CCOC ₆ H ₄ -2,4,6-(CH ₃) ₃ (1 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (4.5 g. C ₉ H ₁₁ Br)	C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂]C=CHCOC ₆ H ₄ - 2,4,6-(CH ₃) ₃ , m.p. 118.5–119.5° (67%)	393
C₁₈H₁₆O₂			
4-CH ₃ OC ₆ H ₄ CO(CH=CH) ₂ C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	4-CH ₃ OC ₆ H ₄ COCH ₂ CH(CH ₂ C ₆ H ₅)CH=CHC ₆ H ₅	506
C ₆ H ₅ COCH ₂ COC ₆ H ₄ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	HO(C ₆ H ₅) ₂ CCH ₂ COC ₆ H ₄ -2,4,6-(CH ₃) ₃	538
2-Mesitylbenzofuran	C ₆ H ₅ MgBr	2-Mesityl-3-phenyl-2,3-dihydrobenzofuran	451
C₁₈H₁₇ON			
2-NCC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (2.6 g.)	CH ₃ MgI (7.1 g. CH ₃ I)	1,1-Dimethyl-3-durylpseudoisoindole (2.6 g., 83%)	235
2-NCC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (7.9 g.)	H ₂ C=CHCH ₂ MgBr (0.15 mole)	1,1-Diallyl-3-durylpseudoisoindole (7.5 g., 76%)	235
2-NCC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (2.6 g.)	C ₆ H ₅ MgBr (15.7 g. C ₆ H ₅ Br)	1,1-Diphenyl-3-durylpseudoisoindole (2.1 g., 51%)	235
2-NCC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (5.2 g.)	4-CH ₃ C ₆ H ₄ MgBr (17.0 g. C ₇ H ₇ Br)	1,1-Di- <i>p</i> -tolyl-3-durylpseudoisoindole (2.6 g., 31%)	235
2-NCC ₆ H ₄ CCC ₆ H-2,3,5,6-(CH ₃) ₄ (7.9 g.)	4-CH ₃ OC ₆ H ₄ MgBr (28.0 g. C ₇ H ₇ BrO)	1,1-Di- <i>p</i> -anisyl-3-durylpseudoisoindole (5.0 g., 36%)	235
2-NCC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (7.9 g.)	1-C ₁₀ H ₇ MgBr (20.7 g. C ₁₀ H ₇ Br)	1,1-Di- <i>α</i> -naphthyl-3-durylpseudoisoindole (9.3 g., 65%)	235
3-NCC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (1.3 g.)	<i>s</i> -C ₄ H ₉ MgBr (3.4 g. C ₄ H ₉ Br)	3- <i>s</i> -C ₄ H ₉ COC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (0.5 g., 31%)	235
3-NCC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (1.3 g.)	C ₆ H ₅ CH ₂ MgCl (3.2 g. C ₇ H ₇ Cl)	3-C ₆ H ₅ CH ₂ COC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (0.95 g., 53%)	235
4-NCC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (2.6 g.)	CH ₃ MgI (7.1 g. CH ₃ I)	Recovered ketone (<i>ca.</i> 50%); 4-CH ₃ C ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (14%)	235

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₈H₁₇ON (<i>cont.</i>)			
4-NCC ₆ H ₄ COCH-2,3,5,6-(CH ₃) ₄ (1.3 g.)	C ₆ H ₅ CH ₂ MgCl (3.2 g. C ₇ H ₇ Cl)	4-C ₆ H ₅ CH ₂ C ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (44%)	235
C₁₈H₁₇O₂N			
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)C ₆ H ₄ -4-CN (5 g.)	CH ₃ MgBr (5 g. Mg)	CH ₃ (4-CH ₃ OC ₆ H ₄)C≡C(C ₂ H ₅)C ₆ H ₄ -4-COCH ₃ (4 g.)*	536
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)C ₆ H ₄ -4-CN (6 g.)	C ₂ H ₅ MgBr (3.6 g. C ₂ H ₅ Br)	C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)[C ₂ H ₅ (4-NCC ₆ H ₄)CH]COH (5 g.)†	536
C₁₈H₁₈O			
C ₆ H ₅ COCH=CHC ₆ H ₂ -2,4,6-(CH ₃) ₃	RMgX	1,4-Addition products, only	401
C ₆ H ₅ CH=CHCOC ₆ H ₂ -2,4,6-(CH ₃) ₃ (50 g.)	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH ₂ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (62 g.)	111
C ₆ H ₅ CH=CHCOC ₆ H ₂ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr (+ Br ₂)	(C ₆ H ₅) ₂ CHCHBrCOC ₆ H ₂ -2,4,6-(CH ₃) ₃ (80-90%)	539
C ₆ H ₅ CH=CHCOC ₆ H ₂ -2,4,6-(CH ₃) ₃ (5 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (8 g. C ₉ H ₁₁ Br)	2,4,6-(CH ₃) ₃ C ₆ H ₂ (C ₆ H ₅)CHCH ₂ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	393
C ₆ H ₅ COC(=CH ₂)C ₆ H ₂ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	No addition product obtained	500
C ₆ H ₅ [2,3,5,6-(CH ₃) ₄ C ₆ H]C≡CO (6 g.)	<i>t</i> -C ₄ H ₉ MgCl (9.3 g. C ₄ H ₉ Cl)	C ₆ H ₅ [2,3,5,6-(CH ₃) ₄ C ₆ H]C≡CHOH (6.5 g., 80%)	501
C₁₈H₁₈O₂			
C ₆ H ₅ COCH ₂ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	CH ₃ Mgl	HO(CH ₃)(C ₆ H ₅)CCH ₂ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (92.4%)	538

* Slow addition of ether-ketone solution to cooled, stirred Grignard reagent solution; twelve hours reflux.

† Dropwise addition of ether-ketone solution to stirred, ice-cooled Grignard reagent solution; one hour stirring with cooling; twelve hours at room temperature.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₈H₁₈O₂ (cont.)			
C ₆ H ₅ COCH ₂ COC ₆ H ₄ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	HO(C ₆ H ₅) ₂ CCH ₂ COC ₆ H ₄ -2,4,6-(CH ₃) ₃	538
C ₆ H ₅ COCOC ₆ H ₄ -2,3,5,6-(CH ₃) ₄	CH ₃ MgI	HO(CH ₃)(C ₆ H ₅)CCOC ₆ H ₄ -2,3,5,6-(CH ₃) ₄	508
C₁₈H₁₈O₃-C₂₀H₂₂O₃			
4-CH ₃ OC ₆ H ₄ COCR=CHC ₆ H ₄ -4-OCH ₃ *	CH ₃ MgI (3 equiv.)	Principal products apparently indenenes (1,2 add'n); traces of 1,4 add'n products	518
4-CH ₃ OC ₆ H ₄ COCR=CHC ₆ H ₄ -4-OCH ₃ *	R'MgBr [†]	4-CH ₃ C ₆ H ₄ COCHRCHR'C ₆ H ₄ -4-OCH ₃ * [†] (ca. 80%)	518
C₁₈H₁₈O₄			
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)C ₆ H ₄ -3-CO ₂ H	C ₂ H ₅ MgI	C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)[C ₂ H ₅ (3-HO ₂ CC ₆ H ₄)CH]COH	540
C₁₈H₂₀O			
C ₆ H ₅ COCH(<i>n</i> -C ₄ H ₉)C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgX	<i>n</i> -C ₄ H ₉ (C ₆ H ₅)[<i>n</i> -C ₄ H ₉ (C ₆ H ₅)CH]COH	461
C ₆ H ₅ COCH(<i>n</i> -C ₄ H ₉)C ₆ H ₅	<i>n</i> -C ₅ H ₁₁ MgX	<i>n</i> -C ₅ H ₁₁ (C ₆ H ₅)[<i>n</i> -C ₄ H ₉ (C ₆ H ₅)CH]COH	461
C ₆ H ₅ CH ₂ COC ₆ H ₄ -4- <i>t</i> -C ₄ H ₉	C ₂ H ₅ MgX	C ₆ H ₅ CH=C(C ₂ H ₅)C ₆ H ₄ -4- <i>t</i> -C ₄ H ₉	441
2-CH ₃ C ₆ H ₄ COC ₆ H ₄ -2,3,5,6-(CH ₃) ₄	<i>t</i> -C ₄ H ₉ MgCl	2-CH ₃ -4- <i>t</i> -C ₄ H ₉ C ₆ H ₃ COC ₆ H ₄ -2,3,5,6-(CH ₃) ₄	528
4-CH ₃ C ₆ H ₄ COCH(<i>n</i> -C ₃ H ₇)C ₆ H ₅	C ₂ H ₅ MgI	HO(C ₂ H ₅)(4-CH ₃ C ₆ H ₄)CCH(<i>n</i> -C ₃ H ₇)C ₆ H ₅	441
C₁₃H₂₀O₂			
2-CH ₃ O-5-CH ₃ C ₆ H ₃ COC ₆ H ₄ -2,4,6-(CH ₃) ₃	C ₂ H ₅ MgBr	2-C ₂ H ₅ -5-CH ₃ C ₆ H ₃ COC ₆ H ₄ -2,4,6-(CH ₃) ₃ (28%) [‡]	519

* R = CH₃, C₂H₅, *n*-C₃H₇.† R' = C₂H₅, *n*-C₃H₇.

‡ Reaction at 30°.

TABLE VI-XVIII (Continued)

Ketonic Comp'd	RMgX	Product(s)	Ref.
C₁₆H₂₀O₂ (cont.)			
2-CH ₃ O-5-CH ₃ C ₆ H ₃ COC ₆ H ₄ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	2-C ₆ H ₅ -5-CH ₃ C ₆ H ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (18%)*	519
2-CH ₃ O-5-CH ₃ C ₆ H ₃ COC ₆ H ₄ -2,4,6-(CH ₃) ₃ (13.4 g.)	C ₆ H ₅ MgBr (16 g. C ₆ H ₅ Br)	2,6-(C ₆ H ₅) ₂ -3-CH ₃ C ₆ H ₂ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (3.5 g., 20%)†	519
2-CH ₃ OC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (10.0 g.)	2-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂]C ₆ H ₄ MgBr (14.5 g. C ₁₆ H ₁₇ Br)	2-[2,3,5,6-(CH ₃) ₃ C ₆ HCO]C ₆ H ₄ C ₆ H ₄ -2-[CH ₂ C ₆ H ₂ -2,4,6-(CH ₃) ₃] (8.2 g., 49%)	644
3-CH ₃ OC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (10 g.)	C ₆ H ₅ CH ₂ MgCl	3-CH ₃ O-4-C ₆ H ₅ CH ₂ C ₆ H ₃ COC ₆ H-2,3,5,6-(CH ₃) ₄ (4.6 g., 34%)	515
4-CH ₃ OC ₆ H ₄ COC ₆ H-2,3,5,6-(CH ₃) ₄ (10 g.)	C ₆ H ₅ CH ₂ MgCl	2-Benzyl-4-methoxy-1,2-dihydrophenyl duryl ketone (0.28 g.)	515
C₁₈H₂₀O₃			
2-(H ₃ CO ₂ CCH ₂ CH ₂ CO)C ₁₀ H ₆ -6- <i>i</i> -C ₃ H ₇	CH ₃ MgI	6- <i>i</i> -C ₃ H ₇ -2-C ₁₀ H ₆ C(CH ₃)=CHCH ₂ CO ₂ H	330
2-(H ₃ CO ₂ CCH ₂ CH ₂ CO)C ₁₀ H ₆ -6- <i>i</i> -C ₃ H ₇	C ₂ H ₅ MgI	6- <i>i</i> -C ₃ H ₇ -2-C ₁₀ H ₆ C(C ₂ H ₅)=CHCH ₂ CO ₂ H	439
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ (10 g.)	C ₂ H ₅ MgBr (2.5 g. Mg)	HO(C ₂ H ₅)(4-CH ₃ OC ₆ H ₄)CCH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ , 2 isomers (10.12 g., 91%)	520
2,3-(CH ₃ O) ₂ C ₆ H ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (4.5 g.)	C ₆ H ₅ CH ₂ MgCl	2-C ₆ H ₅ CH ₂ -3-CH ₃ OC ₆ H ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (0.38 g., 7%)	515
3,4-(CH ₃ O) ₂ C ₆ H ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (12 g.)	C ₆ H ₅ MgBr	3-CH ₃ O-4-C ₆ H ₅ C ₆ H ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (15%)	515
3,4-(CH ₃ O) ₂ C ₆ H ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (8 g.)	C ₆ H ₅ CH ₂ MgCl (8.9 g. C ₇ H ₇ Cl)	3-CH ₃ O-4-C ₆ H ₅ CH ₂ C ₆ H ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (2.1 g., 22%)	515
C₁₈H₂₆O			
CH ₃ COCH=CHCH=C(CH ₃)R†	C ₂ H ₅ OC≡CMgBr	HO(CH ₃)(C ₂ H ₅ OC≡C)CCH=CHCH=C(CH ₃)R	487

* Reaction at 30°.

† Addition of benzene-ketone solution to Grignard reagent solution; eight hours reflux at 60°.

‡ R = β-(1,3,3-trimethyl-2-cyclohexenyl)vinyl.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₈H₂₆O₃N₂			
3,4-Di-4-morpholinyl-4-phenyl-2-butanone (10 g., 1 equiv.)	CH ₃ MgI (3.02 g., 4 equiv. Mg)	HO(CH ₃) ₂ CCH(C ₄ H ₈ NO)CH(C ₄ H ₈ NO)C ₆ H ₅ (5.5 g., 53%); recovered ketone (2 g.)	542
3,4-Di-4-morpholinyl-4-phenyl-2-butanone (16 g., 1 equiv.)	C ₂ H ₅ MgBr (4.8 g., 4 equiv. Mg)	HO(CH ₃) (C ₂ H ₅)CCH(C ₄ H ₈ NO)CH(C ₄ H ₈ NO)-C ₆ H ₅ (10 g., 57%); recovered ketone (4 g.)	542
3,4-Di-4-morpholinyl-4-phenyl-2-butanone (5.9 g.)	C ₆ H ₅ MgBr (1.79 g. Mg)	HO(CH ₃) (C ₆ H ₅)CCH(C ₄ H ₈ NO)CH(C ₄ H ₈ NO)-C ₆ H ₅ (3.6 g.); recovered ketone (1.4 g.)	544
C₁₈H₂₈O			
C ₆ H ₅ CO- <i>n</i> -C ₁₁ H ₂₃ (1.86 mole)	<i>n</i> -C ₈ H ₁₇ MgBr (1.8 mole)	C ₆ H ₅ (<i>n</i> -C ₈ H ₁₇) (<i>n</i> -C ₁₁ H ₂₃)COH (yielding 90% crude olefin)	231
C₁₈H₃₆O			
<i>n</i> -C ₄ H ₉ CO- <i>n</i> -C ₁₃ H ₂₇	<i>n</i> -C ₈ H ₁₇ MgBr	<i>n</i> -C ₄ H ₉ (<i>n</i> -C ₈ H ₁₇) (<i>n</i> -C ₁₃ H ₂₇)COH	496
<i>n</i> -C ₄ H ₉ CO- <i>n</i> -C ₁₃ H ₂₇	<i>n</i> -C ₁₀ H ₂₁ MgBr	<i>n</i> -C ₄ H ₉ (<i>n</i> -C ₁₀ H ₂₁) (<i>n</i> -C ₁₃ H ₂₇)COH	496
C₁₉H₁₃OBBr			
4-BrC ₆ H ₄ COC ₆ H ₄ -4-C ₆ H ₅	C ₆ H ₅ MgBr	4-BrC ₆ H ₄ (C ₆ H ₅)(4-C ₆ H ₅ C ₆ H ₄)COH (yielding 53% triarylmethane)	547
C₁₉H₁₃OCl			
4-ClC ₆ H ₄ COC ₆ H ₄ -4-C ₆ H ₅ (15 g.)	C ₆ H ₅ MgBr (sl. excess)	4-ClC ₆ H ₄ (C ₆ H ₅)(4-C ₆ H ₅ C ₆ H ₄)COH (62%)	547
C₁₉H₁₄O			
C ₆ H ₅ COC ₆ H ₄ -2-C ₆ H ₅ (6.5 g.)	C ₆ H ₅ MgBr (8 g. C ₆ H ₅ Br)	2-C ₆ H ₅ C ₆ H ₄ (C ₆ H ₅) ₂ COH (5.2 g., 63%)	541
C ₆ H ₅ COC ₆ H ₄ -4-C ₆ H ₅	CH ₃ MgI (3 equiv.)	CH ₃ (C ₆ H ₅) (4-C ₆ H ₅ C ₆ H ₄)COH (94%, crude)	418
C ₆ H ₅ COC ₆ H ₄ -4-C ₆ H ₅ (0.10 mole)	<i>n</i> -C ₃ H ₇ MgBr (0.12 mole C ₃ H ₇ Br)	C ₆ H ₅ (4-C ₆ H ₅ C ₆ H ₄)CHOH (48%)*	287
5-Benzoylacenaphthene	C ₆ H ₅ MgBr	Diphenyl-5-acenaphthenylmethanol (55%)	374,545

*From a study of the reducing properties of Grignard reagents in which the yields of reduction products only are reported.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₉H₁₄O₃			
2-C ₆ H ₅ COC ₁₀ H ₆ -1-CO ₂ CH ₃	CH ₃ MgI (<i>ca.</i> 1 equiv.)	3-Methyl-3-phenyl-6,7-benzophthalide (56%)	331
2-o-CH ₃ C ₆ H ₄ COC ₁₀ H ₆ -1-CO ₂ H	CH ₃ MgBr (<i>excess</i>)	3-Methyl-3-o-tolyl-6,7-benzophthalide (85%)	331
2-o-CH ₃ C ₆ H ₄ COC ₁₀ H ₆ -1-CO ₂ H	C ₂ H ₅ MgBr (3 equiv.)	3-o-Tolyl-6,7-benzophthalide (34%); 3-ethyl-3-o-tolyl-6,7-benzophthalide (23%)	331
2-o-CH ₃ C ₆ H ₄ COC ₁₀ H ₆ -1-CO ₂ H	<i>n</i> -C ₁₈ H ₃₇ MgBr (3 equiv.)	3-o-Tolyl-6,7-benzophthalide (28%); <i>n</i> -C ₃₆ H ₇₄	331
1-o-HO ₂ CC ₆ H ₄ C ₁₀ H ₆ -8-CH ₃ (18.5 g.)	CH ₃ MgCl (5 g. Mg)	Recovered keto acid (1.5 g.); unsaponifiable oil (16.5 g.)	205
1-(o-CH ₃ -o'-HO ₂ CC ₆ H ₄ CO)C ₁₀ H ₇ (8.7 g.)	CH ₃ MgBr (18 g. Mg)	3,7-Dimethyl-3- <i>α</i> -naphthylphthalide (6.4 g., 74%)	535
C₁₉H₁₄O₄			
2-o-CH ₃ OC ₆ H ₄ COC ₁₀ H ₆ -1-CO ₂ H (5 g.)	CH ₃ MgBr (17.5 ml., 1.96 M)	3-Methyl-3-o-methoxyphenyl-6,7-benzophthalide (3.9 g., 78%); recovered ketone	548
2-o-CH ₃ OC ₆ H ₄ COC ₁₀ H ₆ -1-CO ₂ H (1.186 g.)	2-CH ₃ OC ₆ H ₄ MgBr (7.5 ml., 1.0 M)	3,3-Di-o-methoxyphenyl-6,7-benzophthalide (1.168 g., 76%)	548
C₁₉H₁₆O			
CH ₃ (C ₆ H ₅)CHCO-1-C ₁₀ H ₇ (16 g.)	CH ₃ MgI (26 g. CH ₃ I)	CH ₃ [CH ₃ (C ₆ H ₅)CH](1-C ₁₀ H ₇)COH (5 g., crude); CH ₃ (C ₆ H ₅)C=C(CH ₃)-1-C ₁₀ H ₇	543
CH ₃ (C ₆ H ₅)CHCO-1-C ₁₀ H ₇ (16.2 g.)	C ₂ H ₅ MgBr (22.0 g. C ₂ H ₅ Br)	C ₂ H ₅ [CH ₃ (C ₆ H ₅)CH](1-C ₁₀ H ₇)COH + CH ₃ (C ₆ H ₅)C=C(C ₂ H ₅)-1-C ₁₀ H ₇ (totaling 14.5 g.)	543
C₁₉H₁₆O₂			
6- <i>p</i> -CH ₃ OC ₆ H ₄ COC ₁₀ H ₆ -2-OCH ₃ (5.9 g.)	CH ₃ MgI (4.7 g. CH ₃ I)	4-CH ₃ OC ₆ H ₄ (2-CH ₃ O-6-C ₁₀ H ₆)C=CH ₂ (4.4 g., 75%)	550

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₉H₁₇ON			
4-(2,5-Dimethyl-1-pyreryl)benzophenone (15 g.)	C ₆ H ₅ CH ₂ MgCl (15 g. C ₇ H ₇ Cl)	1,2-Diphenyl-2-[4-(2,5-dimethyl-1-pyreryl)phenyl]ethene	485
C₁₉H₂₀O			
CH ₃ (C ₆ H ₅)C=CHCOC ₆ H ₄ -2,4,6-(CH ₃) ₃	CH ₃ MgI	C ₆ H ₅ (CH ₃) ₂ CCH ₂ COC ₆ H ₄ -2,4,6-(CH ₃) ₃	538
CH ₃ (C ₆ H ₅)C=CHCOC ₆ H ₄ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	CH ₃ (C ₆ H ₅) ₂ CCH ₂ COC ₆ H ₄ -2,4,6-(CH ₃) ₃ (62%); recovered ketone (25%)	538
C₁₉H₂₁ON			
(CH ₂) ₅ NCH ₂ COC ₆ H ₄ -4-C ₆ H ₅	CH ₃ MgI (<i>ca.</i> 10 equiv.)	CH ₃ [(CH ₂) ₅ NCH ₂](4-C ₆ H ₅ C ₆ H ₄)COH	418
3-[3,4-Dihydro-2(1 <i>H</i>)-isoquinolyl]-4-phenyl-2-butanone	CH ₃ MgI	2-Methyl-3-[3,4-dihydro-2(1 <i>H</i>)-isoquinolyl]-4-phenyl-2-butanol (46%)	551
3-[3,4-Dihydro-2(1 <i>H</i>)-isoquinolyl]-4-phenyl-2-butanone (10 g., 0.036 mole)	C ₆ H ₅ MgBr (3.5 g., 0.144 mole Mg)	2,4-Diphenyl-3-[3,4-dihydro-2(1 <i>H</i>)-isoquinolyl]-2-butanol (5.5 g., 43%)	551
C₁₉H₂₂O			
C ₂ H ₅ (C ₆ H ₅)CHCH ₂ COCH=CHC ₆ H ₅	C ₂ H ₅ MgBr	[C ₂ H ₅ (C ₆ H ₅)CHCH ₂] ₂ CO (<i>ca.</i> quant.)	111
C ₂ H ₅ (C ₆ H ₅)CHCH ₂ COCH=CHC ₆ H ₅ (20 g.)	C ₆ H ₅ MgBr	C ₂ H ₅ (C ₆ H ₅)CHCH ₂ COCH ₂ CH(C ₆ H ₅) ₂ (23 g.); C ₆ H ₅ (C ₆ H ₅)CH=CH[C ₂ H ₅ (C ₆ H ₅)CHCH ₂]- COH (<i>ca.</i> 7%)	111
C ₆ H ₅ COCH(<i>n</i> -C ₅ H ₁₁)C ₆ H ₅	1-C ₁₀ H ₇ MgX	C ₆ H ₅ (1-C ₁₀ H ₇)[<i>n</i> -C ₅ H ₁₁ (C ₆ H ₅)CH]COH	461
2,6-(CH ₃) ₂ C ₆ H ₃ COC ₆ H-2,3,5,6-(CH ₃) ₄	<i>t</i> -C ₄ H ₉ MgCl	2,6-(CH ₃) ₂ -4- <i>t</i> -C ₄ H ₉ C ₆ H ₂ COC ₆ H-2,3,5,6-(CH ₃) ₄ (low yield)	528
4-CH ₃ C ₆ H ₄ COCH(<i>n</i> -C ₄ H ₉)C ₆ H ₅	C ₂ H ₅ MgBr (2 equiv.)	C ₂ H ₅ (4-CH ₃ C ₆ H ₄)[<i>n</i> -C ₄ H ₉ (C ₆ H ₅)CH]COH	441

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₉H₂₂O₃			
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)C ₆ H ₄ -3-OC ₂ H ₅ (2.6 g.)	C ₂ H ₅ MgI (1.5 g. C ₂ H ₅ I)	C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)[C ₂ H ₅ (3-C ₂ H ₅ OC ₆ H ₄ CH]COH (2.4 g.)	546
2,6-(CH ₃ O) ₂ C ₆ H ₃ COC ₆ H-2,3,5,6-(CH ₃) ₄	CH ₃ MgI	2,6-(CH ₃) ₂ C ₆ H ₃ COC ₆ H-2,3,5,6-(CH ₃) ₄ (47%)	528
3,4-(CH ₃ O) ₂ C ₆ H ₃ COC ₆ H-2,3,5,6-(CH ₃) ₄ (3.9 g.)	C ₆ H ₅ CH ₂ MgCl	3-CH ₃ O-4-C ₆ H ₃ CH ₂ C ₆ H ₃ COC ₆ H-2,3,5,6-(CH ₃) ₄ (2 g., 42%)	515
3,5-(CH ₃ O) ₂ C ₆ H ₃ COC ₆ H-2,3,5,6-(CH ₃) ₄ (2.4 g.)	C ₆ H ₅ CH ₂ MgCl	3,5-(CH ₃ O) ₂ -4-C ₆ H ₃ CH ₂ C ₆ H ₂ COC ₆ H-2,3,5,6-(CH ₃) ₄ (0.74 g., 21%)	515
(4- <i>i</i> -C ₃ H ₇ OC ₆ H ₄) ₂ CO	C ₆ H ₅ CH ₂ MgCl	(4- <i>i</i> -C ₃ H ₇ OC ₆ H ₄) ₂ C=CHC ₆ H ₅	549
C₁₉H₂₂O₃ - C₂₀H₂₄O₃			
4-CH ₃ OC ₆ H ₄ COCH ₂ CHRC ₆ H ₄ -4-OCH ₃ *	R'MgX [†] (2 equiv.)	R'(4-CH ₃ OC ₆ H ₄)[R(4-CH ₃ OC ₆ H ₄)CHCH ₂]COH (yielding 80-90% olefin)	518
C₂₀H₁₄O			
2-Benzoylfluorene (10 g.)	C ₆ H ₅ MgBr (10 g. C ₆ H ₅ Br)	Diphenyl-2-fluorenylmethanol (10 g., 78%)	554
C₂₀H₁₄O₂			
1,2-(C ₆ H ₅ CO) ₂ C ₆ H ₄	C ₆ H ₅ MgBr	2-C ₆ H ₅ COC ₆ H ₄ (C ₆ H ₅) ₂ COH or the corresponding hydroxyphthalan (isolated, after heating at 300°, as 10,10-diphenyl-9-anthrone); recovered ketone	555
C₂₀H₁₆O			
C ₆ H ₅ COCH(C ₆ H ₅) ₂	C ₂ H ₅ MgBr	HO(C ₂ H ₅)(C ₆ H ₅)CCH(C ₆ H ₅)	645
C ₆ H ₅ COCH(C ₆ H ₅) ₂ (24 g.)	C ₆ H ₅ MgBr (42 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)OH (ca. 21 g., crude); (C ₆ H ₅) ₂ CH(C ₆ H ₅) ₂ COH (5 g.) [‡]	552

* R = C₂H₅, *n*-C₃H₇.[†] R'MgX = CH₃MgI, C₂H₅MgBr, *n*-C₃H₇MgBr.[‡] Gradual (twenty minutes) addition of powdered ketone to Grignard reagent solution; 4 hours reflux.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₀H₁₆O (<i>cont.</i>)			
C ₆ H ₅ COCH(C ₆ H ₅) ₂ (20 g.)	C ₆ H ₅ MgBr (70 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)OH (8.7 g.); (C ₆ H ₅) ₂ CH(C ₆ H ₅) ₂ COH (5 g.)*	552
C ₆ H ₅ COCH(C ₆ H ₅) ₂ (54.5 g.)	C ₆ H ₅ CH ₂ MgCl (90 ml. C ₇ H ₇ Cl)	C ₆ H ₅ (C ₆ H ₅ CH ₂)[(C ₆ H ₅) ₂ CH]COH (60 g.)	556
C ₆ H ₅ CH ₂ COC ₆ H ₄ -4-C ₆ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ (C ₆ H ₅ CH ₂)(4-C ₆ H ₅ C ₆ H ₄)COH	441
4-CH ₃ C ₆ H ₄ COC ₆ H ₄ -4-C ₆ H ₅	4-CH ₃ C ₆ H ₄ MgBr	4-C ₆ H ₅ C ₆ H ₄ (4-CH ₃ C ₆ H ₄) ₂ COH	431
C₂₀H₁₆O₂			
C ₆ H ₅ COCH(OC ₆ H ₅)C ₆ H ₅	2-C ₆ H ₅ C ₆ H ₄ MgI	C ₆ H ₅ (4-C ₆ H ₅ C ₆ H ₄)[C ₆ H ₅ (C ₆ H ₅ O)CH]COH	471
4-CH ₃ OC ₆ H ₄ COC ₆ H ₄ -4-C ₆ H ₅ (20 g.)	C ₆ H ₅ CH ₂ MgCl (15 g. C ₇ H ₇ Cl)	4-CH ₃ OC ₆ H ₄ (4-C ₆ H ₅ C ₆ H ₄)C≡CHC ₆ H ₅ (10 g.)	485
4-CH ₃ OC ₆ H ₄ COC ₆ H ₄ -4-C ₆ H ₅	4-CH ₃ OC ₆ H ₄ MgBr	4-C ₆ H ₅ C ₆ H ₄ (4-CH ₃ OC ₆ H ₄) ₂ COH	431
5-Anisoylacenaphthene (25 g.)	C ₆ H ₅ CH ₂ MgCl (15 g. C ₇ H ₇ Cl)	1-Anisyl-1-(5-acenaphthenyl)-2-phenylethene (70%)	485
C₂₀H₁₆O₃			
2-o-CH ₃ C ₆ H ₄ COC ₁₀ H ₆ -1-CO ₂ CH ₃	CH ₃ MgI (<i>ca.</i> 1 equiv.)	3-Methyl-3-o-tolyl-6,7-benzophthalide (51% on basis of ketone consumed); recovered ketone	331
C₂₀H₁₆O			
C ₂ H ₅ (C ₆ H ₅)CHCO-2-C ₁₀ H ₇ (10 g.)	CH ₃ MgI (<i>excess</i>)	C ₂ H ₅ (C ₆ H ₅)C≡C(CH ₃)-2-C ₁₀ H ₇ (8 g.); a little carbinol	543
C ₂ H ₅ (C ₆ H ₅)CHCO-2-C ₁₀ H ₇ (10 g.)	C ₂ I ₅ MgBr (<i>excess</i>)	C ₂ H ₅ (C ₆ H ₅)C≡C(C ₂ I ₅)-2-C ₁₀ H ₇ (8.75 g.); a little carbinol	543
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-1-C ₁₀ H ₇ (54.8 g.)	CH ₃ MgI (42.6 g. CH ₃ I)	3-Mesityl-2-methyl-1,2-dihydronaphthalene (58%)	327

* Addition of ketone to Grignard reagent solution; seven hours reflux.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₀H₁₈O (<i>cont.</i>)			
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-1-C ₁₀ H ₇ (5 g.)	C ₆ H ₅ MgBr (10.5 g. C ₆ H ₅ Br)	1-HO-2-C ₆ H ₅ C ₁₀ H ₆ (1.0 g.); 2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ H (0.4 g.); tar	491
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₇ (27.4 g.)	CH ₃ I (excess)	1-CH ₃ C ₁₀ H ₆ -2-[COC ₆ H ₂ -2,4,6-(CH ₃) ₃] (2.0 g.); 1-methyl-2-mesityl-1,2-dihydronaphthalene; 2 unidentified products	327
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₇	RMgX*	Intractable oils	646
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₇	4-CH ₃ C ₆ H ₄ MgBr	1- <i>p</i> -CH ₃ C ₆ H ₄ C ₁₀ H ₆ -2-[COC ₆ H ₂ -2,4,6-(CH ₃) ₃] (48%)	646
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₇	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ MgBr	1- <i>p</i> - <i>i</i> -C ₃ H ₇ C ₆ H ₄ C ₁₀ H ₆ -2-[COC ₆ H ₂ -2,4,6-(CH ₃) ₃] (44%)	646
C₂₀H₂₁ON			
C ₆ H ₅ COC[N(CH ₂) ₅]=CHC ₆ H ₅ (11 g.)	C ₆ H ₅ MgBr (2.5 g. Mg)	C ₆ H ₅ COCH[N(CH ₂) ₅]CH(C ₆ H ₅) ₂ (61%)	559
C₂₀H₂₂O			
[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ CO (8.4 g.)	CH ₃ MgI (3 ml. CH ₃ I)	[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ C=C(CH ₃)OH (7 g., crude)	500
[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ CO	<i>t</i> -C ₄ H ₉ MgCl	[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ C=CHOH (86%)	501
[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ CO (5.6 g.)	C ₆ H ₅ MgBr (4.8 g. C ₆ H ₅ Br)	[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ C=C(C ₆ H ₅)OH (3 g.)	500
C₂₀H₂₃ON			
C ₆ H ₅ COCH[N(CH ₂) ₅]CH ₂ C ₆ H ₅ (2.9 g.)	C ₆ H ₅ MgBr (0.96 g. Mg)	HO(C ₆ H ₅) ₂ CCH[N(CH ₂) ₅]CH ₂ C ₆ H ₅	559
C₂₀H₂₄O			
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂ C ₆ H ₂ -2,4,6-(CH ₃) ₃	CH ₃ MgX	Enolization (96%) [†]	312

* RMgX = (CH₂)₅CHMgX, 4-ClC₆H₄MgBr, C₆H₅CH₂MgCl.[†] "Grignard machine" study.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₀H₂₄O (<i>cont.</i>)			
2,4,6-(CH ₃) ₅ C ₆ H ₂ COCH ₂ C ₆ H ₂ -2,4,6-(CH ₃) ₃	C ₂ H ₅ MgBr	Enolization*	312
2,4,6-(CH ₃) ₃ C ₆ H ₂ COC ₆ H-2,3,5,6-(CH ₃) ₄	<i>s</i> -C ₄ H ₉ MgBr	"No product"	528
C₂₀H₂₄ON₂			
<i>N</i> -Methylcinchotoxine	CH ₃ MgI (or C ₆ H ₅ MgBr)	Recovered ketone	418
C₂₀H₂₄O₃			
4-CH ₃ OC ₆ H ₄ COCH ₂ CH(<i>i</i> -C ₃ H ₇)C ₆ H ₄ -4-OCH ₃	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CH(4-CH ₃ OC ₆ H ₄)[<i>i</i> -C ₃ H ₇ (4-CH ₃ OC ₆ H ₄)-CHCH ₂]COH	514
4-CH ₃ OC ₆ H ₄ COCH(CH ₃)CH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ ("B" isomer, m.p., 72°)	CH ₃ MgI (2 equiv.)	After dehydr'n: 4-CH ₃ OC ₆ H ₄ C(=CH ₂)-CH(CH ₃)CH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ , b.p. (1 mm.), 175-177° (<i>ca.</i> 80%)	553
4-CH ₃ OC ₆ H ₄ COCH(CH ₃)CH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ ("A" isomer, m.p., 52°)	C ₂ H ₅ MgBr (2 equiv.)	After dehydr'n: 4-CH ₃ OC ₆ H ₄ C(=CHCH ₃)-CH(CH ₃)CH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ , b.p. (1 mm.), 175° (<i>ca.</i> 80%)	553
C₂₀H₂₄O₄			
CH ₃ COC(CH ₃)(CO ₂ C ₂ H ₅)CH ₂ CH ₂ -1-C ₁₀ H ₆ -6-OCH ₃ (7.7 parts)	C ₂ H ₅ MgBr (3.3 parts C ₂ H ₅ Br)	HO(CH ₃)(C ₂ H ₅)CC(CH ₃)(CO ₂ C ₂ H ₅)CH ₂ CH ₂ -1-C ₁₀ H ₆ -6-OCH ₃ (8.1 parts)	560
C₂₀H₃₀ON₂			
CH ₃ COCH[N(CH ₂) ₅]CH[N(CH ₂) ₅]C ₆ H ₅	C ₆ H ₅ MgBr	HO(CH ₃)(C ₆ H ₅)CCH[N(CH ₂) ₅]CH[N(CH ₂) ₅]-C ₆ H ₅ (13%)	561

*"Grignard machine" study.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₀H₃₂O₃ 2,5-(CH ₃ O) ₂ C ₆ H ₃ CO- <i>n</i> -C ₁₁ H ₂₃	CH ₃ MgI	CH ₃ [2,5-(CH ₃ O) ₂ C ₆ H ₃]C≡CH- <i>n</i> -C ₁₀ H ₂₁ (60-70%)	557
C₂₀H₃₈O₂ [C ₂ H ₅ CO(CH ₂) ₇ —] ₂	<i>n</i> -C ₁₆ H ₃₃ C≡CMgBr	[HO(C ₂ H ₅)(<i>n</i> -C ₁₆ H ₃₂ C≡C)C(CH ₂) ₇ —] ₂ (88%)	558
C₂₀H₄₀O <i>n</i> -C ₄ H ₉ CO- <i>n</i> -C ₁₅ H ₃₁ <i>n</i> -C ₄ H ₉ CO- <i>n</i> -C ₁₅ H ₃₁	<i>n</i> -C ₆ H ₁₃ MgBr <i>n</i> -C ₁₀ H ₂₁ MgBr	<i>n</i> -C ₄ H ₉ (<i>n</i> -C ₆ H ₁₃)(<i>n</i> -C ₁₅ H ₃₁)COH <i>n</i> -C ₄ H ₉ (<i>n</i> -C ₁₀ H ₂₁)(<i>n</i> -C ₁₅ H ₂₁)COH	496 496
C₂₁H₁₄O 2-Benzoylphenanthrene 3-Benzoylphenanthrene Anthraphenone (5 g.) (1-C ₁₀ H ₇) ₂ CO (1-C ₁₀ H ₇) ₂ CO	C ₆ H ₅ MgBr C ₆ H ₅ MgBr C ₆ H ₅ MgBr (4 equiv.) C ₆ H ₅ C≡CMgBr 1-C ₁₀ H ₇ MgBr	Diphenyl-2-phenanthrylmethanol (53%) Diphenyl-3-phenanthrylmethanol (89%) Recovered ketone (3.5 g.); 9,9'-bis-(10-benzoyl-9,10-dihydroanthracyl) C ₆ H ₅ C≡C(1-C ₁₀ H ₇) ₂ COH (90%) (1-C ₁₀ H ₇) ₃ COH	562 562 565 65 563, 564
C₂₁H₁₆O C ₆ H ₅ COCH=C(C ₆ H ₅) ₂ (40 g.) C ₆ H ₅ COCH=C(C ₆ H ₅) ₂ C ₆ H ₅ COC(C ₆ H ₅)=CHC ₆ H ₅ C ₆ H ₅ COC(C ₆ H ₅)=CHC ₆ H ₅ , m. 102° (5.0 g.)	C ₆ H ₅ MgBr C ₆ H ₅ MgBr (2 equiv.) CH ₃ MgI (4 equiv.) C ₂ H ₅ MgBr	(C ₆ H ₅) ₂ C=CH(C ₆ H ₅) ₂ COH; diene; C ₆ H ₅ COCH ₂ C(C ₆ H ₅) ₃ (8 g.) (C ₆ H ₅) ₂ C=CH(C ₆ H ₅) ₂ COH; diene HO(CH ₃)(C ₆ H ₅)C(C ₆ H ₅)=CHC ₆ H ₅ (53.6-63.4%) C ₆ H ₅ COCH(C ₆ H ₅)CH(C ₂ H ₅)C ₆ H ₅ (6.2 g., yielding 0.8 g. of isomer m. 170° and 5.1 g. of isomer m. 92°)	111 111, 455 591 645

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₁H₁₆O (<i>cont.</i>)			
C ₆ H ₅ COC(C ₆ H ₅)=CHC ₆ H ₅ , m. 88-89° (5.0 g.)	C ₂ H ₅ MgBr	C ₆ H ₅ COCH(C ₆ H ₅)CH(C ₂ H ₅)C ₆ H ₅ (6.3 g., yielding 0.7 g. of isomer m. 170° and 5.3 g. of isomer m. 92°)	645
C ₆ H ₅ COC(C ₆ H ₅)=CHC ₆ H ₅ (50 g.)	C ₆ H ₅ MgBr (10 g. Mg)	C ₆ H ₅ COCH(C ₆ H ₅)CH(C ₆ H ₅) ₂ (61 g., 95.8%)	591
C ₆ H ₅ COC(C ₆ H ₅)=CHC ₆ H ₅ (25 g.)	C ₆ H ₅ CH ₂ MgCl (12.6 g. C ₇ H ₇ Cl)	C ₆ H ₅ COCH(C ₆ H ₅)CH(C ₆ H ₅)CH ₂ C ₆ H ₅ (8.5 g.)	435
2-Benzoyl-9-methylfluorene	C ₆ H ₅ MgBr	Diphenyl-2-(9-methylfluorenyl)methanol	554
Dihydroanthraphenone (5.0 g.)	C ₆ H ₅ MgBr (9.5 g. C ₆ H ₅ Br)	9-(9,10-Dihydroanthracyl)diphenylmethanol (4.0 g.)	565
C₂₁H₁₆O₂			
C ₆ H ₅ COCOCH(C ₆ H ₅) ₂	CH ₃ MgI	C ₆ H ₅ COC(OH)(CH ₃)CH(C ₆ H ₅) ₂ *	566
C ₆ H ₅ COCOCH(C ₆ H ₅) ₂	CH ₃ MgI	(C ₆ H ₅) ₂ CHCOC(OH)(CH ₃)C ₆ H ₅ †	566
C ₆ H ₅ COCOCH(C ₆ H ₅) ₂ (10 g.)	C ₆ H ₅ MgBr (excess)	C ₆ H ₅ COC(OH)(C ₆ H ₅)CH(C ₆ H ₅) ₂ (9.5 g.)	566
Benzylidene-4-phenylacetophenone oxide	C ₆ H ₅ MgBr	[C ₆ H ₅ (<i>p</i> -C ₆ H ₅ C ₆ H ₄)COH—] ₂ ; HO(C ₆ H ₅)- CHCH(C ₆ H ₅)C(C ₆ H ₅)(C ₆ H ₄ -4-C ₆ H ₅)OH	492
1,1-Diphenyl-2-benzoylperoxyethane	C ₂ H ₅ MgI (excess)	(C ₆ H ₅) ₂ CHCHO	430
1,1-Diphenyl-2-benzoylperoxyethane	C ₆ H ₅ MgBr (excess)	(C ₆ H ₅) ₂ CHCHO; (C ₆ H ₅) ₂ CHCH ₂ OH; (C ₆ H ₅ —) ₂	430
C₂₁H₁₆O₅S			
C ₆ H ₅ COCH=C(C ₆ H ₅)SO ₂ C ₆ H ₅ (7.0 g.)	C ₆ H ₅ MgBr (4 equiv.)	HO(C ₆ H ₅) ₂ CCH=C(C ₆ H ₅)SO ₂ C ₆ H ₅ ‡	654
C ₆ H ₅ COCH=C(C ₆ H ₅)SO ₂ C ₆ H ₅ (10.0 g.)	C ₆ H ₅ MgBr (2.25 g. Mg)	HO(C ₆ H ₅) ₂ CCH=C(C ₆ H ₅)SO ₂ C ₆ H ₅ (57%); HO(C ₆ H ₅) ₂ CCH(C ₆ H ₅)CH(C ₆ H ₅)SO ₂ C ₆ H ₅ , m. 178° (15%); HO(C ₆ H ₅) ₂ CCH(C ₆ H ₅)CH- (C ₆ H ₅)SO ₂ C ₆ H ₅ , m. 223° (12%)§	654

* Addition of Grignard reagent solution to Et₂O-ketone solution.† Addition of Et₂O-ketone solution to Grignard reagent solution.

‡ Several hours stirring at room temperature.

§ Two hours reflux.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₁H₁₆O₃S (<i>cont.</i>)			
C ₆ H ₅ COCH=C(C ₆ H ₅)SO ₂ C ₆ H ₅ (10.0 g.)	C ₆ H ₅ MgBr (2.25 g. Mg)	HO(C ₆ H ₅) ₂ CCH=C(C ₆ H ₅)SO ₂ C ₆ H ₅ (22%); HO(C ₆ H ₅) ₂ CCH(C ₆ H ₅)CH(C ₆ H ₅)SO ₂ C ₆ H ₅ , m. 178° (26%); (C ₆ H ₅) ₂ C=C(C ₆ H ₅)CH- (C ₆ H ₅)SO ₂ C ₆ H ₅ (?), m. 196° (32%)*	654
C₂₁H₁₇OBr			
C ₆ H ₅ COCHBrCH(C ₆ H ₅) ₂	C ₆ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅) ₂ ; (C ₆ H ₅ —) ₂	275
C ₆ H ₅ COCHBrCH(C ₆ H ₅) ₂ (25 g.)	C ₆ H ₅ C≡CMgBr (11.5 g. C ₆ H ₅ C≡CHI)	HO(C ₆ H ₅)(C ₆ H ₅ C≡C)CCHBrCH(C ₆ H ₅) ₂ (19 g.)	567
C₂₁H₁₇OCl			
4-ClC ₆ H ₄ COCH ₂ CH(C ₆ H ₅) ₂ (45 g.)	C ₆ H ₅ MgBr (25 g. C ₆ H ₅ Br)	4-ClC ₆ H ₄ (C ₆ H ₅)[(C ₆ H ₅) ₂ CHCH ₂]COH (40 g.)	453
C₂₁H₁₇OI			
C ₆ H ₅ COCHICH(C ₆ H ₅) ₂	C ₆ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅) ₂ (94%); C ₆ H ₅ I (96.5%)	437
C₂₁H₁₈O			
C ₆ H ₅ COCH ₂ CH(C ₆ H ₅) ₂	CH ₃ MgBr	CH ₃ (C ₆ H ₅)C≡CHCH(C ₆ H ₅) ₂	223
C ₆ H ₅ COCH ₂ CH(C ₆ H ₅) ₂	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH ₂ (C ₆ H ₅) ₂ COH	569
C ₆ H ₅ COCH(C ₆ H ₅)CH ₂ C ₆ H ₅	<i>t</i> -C ₄ H ₉ MgCl	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)[C ₆ H ₅ (C ₆ H ₅ CH ₂)CH]COH	648
DL-C ₆ H ₅ COCH(C ₆ H ₅)CH ₂ C ₆ H ₅ (5 g.)	C ₆ H ₅ MgBr (11.5 g. C ₆ H ₅ Br)	C ₆ H ₅ CH ₂ (C ₆ H ₅)CH(C ₆ H ₅) ₂ COH (4 g.)	568
C ₆ H ₅ COCH(C ₆ H ₅)CH ₂ C ₆ H ₅ (23 g.)	C ₆ H ₅ CH ₂ MgCl (14 ml. C ₇ H ₇ Cl)	C ₆ H ₅ (C ₆ H ₅ CH ₂)[C ₆ H ₅ CH ₂ (C ₆ H ₅)CH]COH (22 g., purified)	435
C ₆ H ₅ COCH(C ₆ H ₅)C ₆ H ₄ -4-CH ₃ (2 g.)	4-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ (4-CH ₃ C ₆ H ₄)[C ₆ H ₅ (4-CH ₃ C ₆ H ₄)CH]COH (0.5 g.)	426

*Six hours reflux.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₁H₁₈OS			
C ₆ H ₅ COCH(C ₆ H ₅)SC ₆ H ₄ -4-CH ₃	C ₆ H ₅ MgBr (excess)	HO(C ₆ H ₅) ₂ CCH(C ₆ H ₅)SC ₆ H ₄ -4-CH ₃ (<i>ca.</i> quant.)	652
C₂₁H₁₈O₂			
C ₆ H ₅ COC(OCH ₃)(C ₆ H ₅) ₂	C ₆ H ₅ MgBr	HO(C ₆ H ₅) ₂ CC(OCH ₃)(C ₆ H ₅) ₂ (66%)	570
C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)C ₆ H ₄ -2-OH (5 g.)	C ₆ H ₅ MgBr	2-HOC ₆ H ₄ (C ₆ H ₅)CHCH ₂ (C ₆ H ₅) ₂ COH (4.3 g.)	571, 572
C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)C ₆ H ₄ -2-OH	C ₆ H ₅ MgBr	2,4-Diphenylflavan	572
4-CH ₃ OC ₆ H ₄ COC ₆ H ₄ -2-CH ₂ C ₆ H ₅	4-CH ₃ OC ₆ H ₄ MgI	2-C ₆ H ₅ CH ₂ C ₆ H ₄ (4-CH ₃ OC ₆ H ₄) ₂ COH	573
C₂₁H₁₉O₅Br			
1,1-Dicarbomethoxy-2-benzoyl-3-(3-bromo-4-methoxyphenyl)cyclopropane	C ₂ H ₅ MgBr	1,1-Dicarbomethoxy-2-(α -hydroxy- α -phenylpropyl)-3-(3-bromo-4-methoxyphenyl)cyclopropane (2 isomers, m. 135° and 161°)	574
C₂₁H₂₀O₂			
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-1-C ₁₀ H ₆ -2-OCH ₃	CH ₃ MgI	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-1-C ₁₀ H ₆ -2-CH ₃ (56%)	519
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-1-C ₁₀ H ₆ -2-OCH ₃ (7.6 g.)	C ₂ H ₅ MgBr (4.2 g. C ₂ H ₅ Br)	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-1-C ₁₀ H ₆ -2-C ₂ H ₅ (6 g., 80%)	519
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-1-C ₁₀ H ₆ -2-OCH ₃	<i>n</i> -C ₄ H ₉ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-1-C ₁₀ H ₆ -2- <i>n</i> -C ₄ H ₉ (55%)	519
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-1-C ₁₀ H ₆ -2-OCH ₃	C ₆ H ₅ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-1-C ₁₀ H ₆ -2-C ₆ H ₅ (59%)	519
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-1-C ₁₀ H ₆ -2-OCH ₃	1-C ₁₀ H ₇ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-1-C ₁₀ H ₆ -2- α -C ₁₀ H ₇ (76%)	519
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₆ -1-OCH ₃ (0.5 g.)	CH ₃ MgI (1.2 g. CH ₃ I)	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₆ -1-CH ₃ (74%)	646
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₆ -1-OCH ₃	C ₂ H ₅ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₆ -1-C ₂ H ₅ (73%)	646
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₆ -1-OCH ₃	C ₆ H ₅ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₆ -1-C ₆ H ₅ (69%)	646
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₆ -1-OCH ₃ (1.1 g.)	C ₆ H ₅ CH ₂ MgCl (0.9 g. C ₇ H ₇ Cl)	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₆ -1-CH ₂ C ₆ H ₅ (91%)	646

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₂₁H₂₀O₂ (cont.)			
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₆ -1-OCH ₃	4-CH ₃ C ₆ H ₄ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₆ -1-C ₆ H ₄ -4-CH ₃ (75%)	646
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₆ -1-OCH ₃	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO-2-C ₁₀ H ₆ -1-C ₆ H ₄ -4- <i>i</i> -C ₃ H ₇ (56%)	646
C₂₁H₂₂O			
1-Mesitoyl-2-methyl-1,2-dihydronaphthalene	CH ₃ MgI	CH ₄ (0.98 equiv.); enolate, isolated as acetate	327
1-Mesitoyl-2-methyl-1,2-dihydronaphthalene	C ₂ H ₅ MgI (3-fold excess)	Enolate, isolated as peroxide, which on decomp'n yielded mesitoic acid and 3,3'-dimethyl-4,4'-dihydroxy-1,1'-binaphthyl	327
2,4,6-(CH ₃) ₃ C ₆ H ₂ COC≡CC ₆ H ₂ -2,4,6-(CH ₃) ₃ (4.39 g.)	CH ₃ MgI (6.5 g. CH ₃ I)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH=C(CH ₃)C ₆ H ₂ -2,4,6-(CH ₃) ₃ (4.2 g., 91%), separated into isomer "A," m. 101-103° (3.28 g., 72%) and isomer "B," m. 75-76° (0.13 g., 2.9%)	393
2,4,6-(CH ₃) ₃ C ₆ H ₂ COC≡CC ₆ H ₂ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	C ₆ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂]C≡CHCOC ₆ H ₂ -2,4,6-(CH ₃) ₃ , m. 119-120°	393
2,4,6-(CH ₃) ₃ C ₆ H ₂ COC≡CC ₆ H ₂ -2,4,6-(CH ₃) ₃	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ C≡CHCOC ₆ H ₂ -2,4,6-(CH ₃) ₃ (35%); C ₃₀ H ₃₆ O, m. 182-183°	393
C₂₁H₂₄O			
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH=CHC ₆ H ₂ -2,4,6-(CH ₃) ₃	RMgX	1,4-Addition products, only	401
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH=CHC ₆ H ₂ -2,4,6-(CH ₃) ₃ (11.5 g.)	CH ₃ MgI (13.0 g. CH ₃ I)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂ CH(CH ₃)C ₆ H ₂ -2,4,6-(CH ₃) ₃ ("high yield")	393
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH=CHC ₆ H ₂ -2,4,6-(CH ₃) ₃	C ₆ H ₅ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂ CH(C ₆ H ₅)C ₆ H ₂ -2,4,6-(CH ₃) ₃	393

TABLE VI-XVIII (Continued)

Ketonic Comp'd	RMgX	Product(s)	Ref.
C₂₁H₂₄O (<i>cont.</i>)			
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH=CHC ₆ H ₂ - 2,4,6-(CH ₃) ₃ (8.42 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (<i>ca.</i> 0.1 mole)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂ CH[C ₆ H ₂ -2,4,6-(CH ₃) ₃] ₂ (46%)	393
2,4,6-(CH ₃) ₃ C ₆ H ₂ COC[C ₆ H ₂ -2,4,6-(CH ₃) ₃]=CH ₂	CH ₃ MgI	C ₂ H ₅ [2,4,6-(CH ₃) ₃ C ₆ H ₂]C=C[C ₆ H ₂ -2,4,6-(CH ₃) ₃]OH	575
2,4,6-(CH ₃) ₃ C ₆ H ₂ COC[C ₆ H ₂ -2,4,6-(CH ₃) ₃]=CH ₂	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ [2,4,6-(CH ₃) ₃ C ₆ H ₂]C=C[C ₆ H ₂ -2,4,6-(CH ₃) ₃]OH	575
C₂₁H₂₆O			
2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -4- <i>t</i> -C ₄ H ₉ (4.4 g.)	CH ₃ MgI (2.8 ml. CH ₃ I)	2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -2-CH ₃ -4- <i>t</i> -C ₄ H ₉	528
C₂₁H₂₆O₃			
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)CH(C ₂ H ₅)- C ₆ H ₄ -4-OCH ₃ ["A" isomer, b. (2 mm.) 181-183°]	CH ₃ MgI (2 equiv.)	After dehydration: 4-CH ₃ OC ₆ H ₄ C(=CH ₂)- [CH(C ₂ H ₅)] ₂ C ₆ H ₄ -4-OCH ₃ , b. (1 mm.) 174- 176°. (<i>ca.</i> 80%)	353
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)CH(C ₂ H ₅)- C ₆ H ₄ -4-OCH ₃ ["A" isomer, b. (2 mm.) 181-183°]	C ₂ H ₅ MgBr (2 equiv.)	After dehydration: 4-CH ₃ OC ₆ H ₄ C(=CHCH ₃)- [CH(C ₂ H ₅)] ₂ C ₆ H ₄ -4-OCH ₃ , b. (1 mm.) 178° (<i>ca.</i> 80%)	353
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)CH(C ₂ H ₅)- C ₆ H ₄ -4-OCH ₃ ["A" isomer, b. (2 mm.) 181-183°]	<i>n</i> -C ₃ H ₇ MgBr (2 equiv.)	After dehydration: 4-CH ₃ OC ₆ H ₄ C- (=CHC ₂ H ₅)[CH(C ₂ H ₅)] ₂ C ₆ H ₄ -4-OCH ₃ , b. (1 mm.) 190°, (<i>ca.</i> 80%)	353
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)CH(C ₂ H ₅)- C ₆ H ₄ -4-OCH ₃ ("B" isomer, m. 82°)	CH ₃ MgI (2 equiv.)	After dehydration: 4-CH ₃ OC ₆ H ₄ C(=CH ₂)- [CH(C ₂ H ₅)] ₂ C ₆ H ₄ -4-OCH ₃ , m. 44° (<i>ca.</i> 80%)	353
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)CH(C ₂ H ₅)- C ₆ H ₄ -4-OCH ₃ ("B" isomer, m. 82°)	C ₂ H ₅ MgBr (2 equiv.)	After dehydration: 4-CH ₃ OC ₆ H ₄ C(=CHCH ₃)- [CH(C ₂ H ₅)] ₂ C ₆ H ₄ -4-OCH ₃ , b. (1 mm.) 190° (<i>ca.</i> 80%)	353
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)CH(C ₂ H ₅)- C ₆ H ₄ -4-OCH ₃ ("B" isomer, m. 82°)	<i>n</i> -C ₃ H ₇ MgBr (2 equiv.)	After dehydration: 4-CH ₃ OC ₆ H ₄ C- (=CHC ₂ H ₅)[CH(C ₂ H ₅)] ₂ C ₆ H ₄ -4-OCH ₃ , b. (1 mm.) 190° (<i>ca.</i> 80%)	353

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₂₁H₂₈ON₂			
[4-(C ₂ H ₅) ₂ NC ₆ H ₄] ₂ CO	CH ₃ MgI	[4-(C ₂ H ₅) ₂ NC ₆ H ₄] ₂ C=CH ₂	477
[4-(C ₂ H ₅) ₂ NC ₆ H ₄] ₂ CO	C ₂ H ₅ MgI	[4-(C ₂ H ₅) ₂ NC ₆ H ₄] ₂ C=CHCH ₃	477
C₂₂H₁₆O₂			
C ₆ H ₅ COCH=C(C ₆ H ₅)COC ₆ H ₅ (15 parts)	C ₆ H ₅ MgBr (35 parts C ₆ H ₅ Br)	2,3,4,5-Tetraphenylfuran (40-60%); [C ₆ H ₅ (C ₆ H ₅ CO)CH—] ₂ ; [C ₆ H ₅ (C ₆ H ₅ CO)- C=] ₂ ; "dihydroxylepidine"	602
C₂₂H₁₉ON			
1-Benzyl-2-phenyl-3-benzoylethyl- eneimine	CH ₃ MgI (4 equiv.)	1-Benzyl-2,4-diphenyl-4-hydroxy- α -butyl- eneimine (85%)	484
1-Benzyl-2-phenyl-3-benzoylethyl- eneimine	C ₆ H ₅ MgBr (4 equiv.)	1-Benzyl-2,4,4-triphenyl-4-hydroxypropyl- eneimine (90%)	484
1-Benzyl-2-phenyl-3-benzoylethyl- eneimine	4-CH ₃ C ₆ H ₄ MgBr (4 equiv.)	1-Benzyl-2,4-diphenyl-4- <i>p</i> -tolyl-4-hydroxy- propyleneimine, m.p. 138° (85%)	484
C₂₂H₂₀O			
C ₆ H ₅ CH ₂ COCH(C ₆ H ₅)CH ₂ C ₆ H ₅ (3.0 g.)	C ₆ H ₅ CH ₂ MgCl (3.8 g. C ₇ H ₇ Cl)	C ₆ H ₅ (C ₆ H ₅ CH ₂)CH(C ₆ H ₅ CH ₂) ₂ COH (3.6 g., 92%)	498
C₂₂H₂₀O₂			
C ₆ H ₅ COC(OC ₂ H ₅)(C ₆ H ₅) ₂	C ₆ H ₅ MgBr	HO(C ₆ H ₅) ₂ CC(OC ₂ H ₅)(C ₆ H ₅) ₂ (75%)	570
HO(CH ₃)(C ₆ H ₅)CCOCH(C ₆ H ₅) ₂ (2 g.)	C ₆ H ₅ MgBr (2 g. Mg)	HO(CH ₃)(C ₆ H ₅)CC(OH)(C ₆ H ₅)CH(C ₆ H ₅) ₂ (0.5 g.)	566
C₂₂H₂₄O₂			
[2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH=] ₂ (50 g.)	<i>t</i> -C ₄ H ₉ MgCl (5 equiv.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ C(OH)=CHCH(<i>t</i> - C ₄ H ₉)COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (29.6 g.)	576

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₂₂H₂₄O₂ (<i>cont.</i>)			
[2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH=] ₂	C ₆ H ₅ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂ CH(C ₆ H ₅)COC ₆ H ₅ 2,4,6-(CH ₃) ₃ (59-60%)	488
C₂₂H₂₆O			
2,4,6-(CH ₃) ₃ C ₆ H ₂ COC(CH ₃)=CHC ₆ H ₂ - 2,4,6-(CH ₃) ₃ (8.9 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (0.08 mole)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH(CH ₃)CH[C ₆ H ₂ -2,4,6- (CH ₃) ₃] ₂ (46%)	393
2,3,4,6-(CH ₃) ₄ C ₆ HCOC[C ₆ H ₂ -2,4,6- (CH ₃) ₃]=CH ₂	C ₆ H ₅ MgBr	2,3,4,6-(CH ₃) ₄ C ₆ HC(OH)=C(C ₆ H ₅)C ₆ H ₂ - 2,4,6-(CH ₃) ₃	575
2,3,5,6-(CH ₃) ₄ C ₆ HCOC[C ₆ H ₂ -2,4,6- (CH ₃) ₃]=CH ₂	CH ₃ MgI	2,3,5,6-(CH ₃) ₄ C ₆ HC(OH)=C(C ₂ H ₅)C ₆ H ₂ - 2,4,6-(CH ₃) ₃	575
C₂₂H₂₈O₃			
4-CH ₃ OC ₆ H ₄ COCH(<i>n</i> -C ₃ H ₇)CH(C ₂ H ₅)- C ₆ H ₄ -4-OCH ₃ ["A" isomer; b. (2 mm.), 183-185°]	CH ₃ MgI (2 equiv.)	After dehydration: 4-CH ₃ OC ₆ H ₄ C(=CH ₂)- CH(<i>n</i> -C ₃ H ₇)CH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ , b. (1 mm.), 186-188° (<i>ca.</i> 80%)	553
4-CH ₃ OC ₆ H ₄ COCH(<i>n</i> -C ₃ H ₇)CH(C ₂ H ₅)- C ₆ H ₄ -4-OCH ₃ ["A" isomer; b. (2 mm.), 182-185°]	C ₂ H ₅ MgBr (2 equiv.)	After dehydr'n: 4-CH ₃ OC ₆ H ₄ C(=CHCH ₃)- CH(<i>n</i> -C ₃ H ₇)CH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ , b. (1 mm.), 185° (<i>ca.</i> 80%)	553
4-CH ₃ OC ₆ H ₄ COCH(<i>n</i> -C ₃ H ₇)CH(C ₂ H ₅)- C ₆ H ₄ -4-OCH ₃ ("B" isomer, m. 69°)	CH ₃ MgI (2 equiv.)	After dehydr'n: 4-CH ₃ OC ₆ H ₄ C(=CH ₂)CH- (<i>n</i> -C ₃ H ₇)CH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ , b. (1 mm.), 185° (<i>ca.</i> 80%)	553
4-CH ₃ OC ₆ H ₄ COCH(<i>n</i> -C ₃ H ₇)CH(C ₂ H ₅)- C ₆ H ₄ -4-OCH ₃ ("B" isomer, m. 69°)	C ₂ H ₅ MgBr (2 equiv.)	After dehydr'n: 4-CH ₃ OC ₆ H ₄ C(=CHCH ₃)- CH(<i>n</i> -C ₃ H ₇)CH(C ₂ H ₅)C ₆ H ₄ -4-OCH ₃ , b. (1 mm.), 174-177° (<i>ca.</i> 80%)	553
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)CH(<i>n</i> -C ₃ H ₇)- C ₆ H ₄ -4-OCH ₃ ("A" isomer, m. 62°)	CH ₃ MgI (2 equiv.)	After dehydr'n: 4-CH ₃ OC ₆ H ₄ C(=CH ₂)CH- (C ₂ H ₅)CH(<i>n</i> -C ₃ H ₇)C ₆ H ₄ -4-OCH ₃ , b. (1 mm.), 185° (<i>ca.</i> 80%)	553

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₂₂H₂₈O₃ (<i>cont.</i>)			
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)CH(<i>n</i> -C ₃ H ₇)-C ₆ H ₄ -4-OCH ₃ ("B" isomer, m. 93°)	CH ₃ MgI (2 equiv.)	After dehydr'n: 4-CH ₃ OC ₆ H ₄ C(=CH ₂)-CH(C ₂ H ₅)CH(<i>n</i> -C ₃ H ₇)C ₆ H ₄ -4-OCH ₃ , b. (1 mm.), 187° (<i>ca.</i> 80%)	553
C₂₁H₃₆O			
C ₆ H ₅ CO- <i>n</i> -C ₁₅ H ₃₁	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ (C ₆ H ₅)(<i>n</i> -C ₁₅ H ₃₁)COH; "olefin" (<i>i.e.</i> , dehydr'n product)	222
C₂₂H₃₆O₃			
2,5-(CH ₃ O) ₂ C ₆ H ₃ CO- <i>n</i> -C ₁₃ H ₂₇	CH ₃ MgI	2,5-(CH ₃ O) ₂ C ₆ H ₃ C(CH ₃)=CH- <i>n</i> -C ₁₂ H ₂₅ (60-70%)	557
C₂₃H₁₂OBr₂			
1-Benzoyl-6,8-dibromopyrene* (25 g.)	C ₆ H ₅ MgBr (24 g. C ₆ H ₅ Br)	Diphenyl-6,8-dibromo-1-pyrenylmethanol* (22 g.)	579
C₂₃H₁₄O			
1-Benzoylpyrene* (16 g.)	C ₆ H ₅ MgBr (14 g. C ₆ H ₅ Br)	Diphenyl-1-pyrenylmethanol* (19.5 g., with 1 mole EtOH of cryst'n)	579
C₂₃H₁₈O₂			
4-Phenacylflavene†	C ₆ H ₅ MgBr	4-(β-Hydroxy-β,β-diphenylethyl)flavene	572,571
C₂₃H₂₀O			
C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)CH=CHC ₆ H ₅	C ₆ H ₅ MgBr (2 equiv.)	HO(C ₆ H ₅) ₂ CCH ₂ CH(C ₆ H ₅)CH≡CHC ₆ H ₅ (quant.)	581

*The numbering of "The Ring Index" rather than that of the authors cited is here employed.

†2-Phenyl-4-phenacyl-1,4-benzopyran, or 2-phenyl-4-phenacyl-1,4-chromene.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₂₃H₂₀O (<i>cont.</i>)			
(C ₆ H ₅) ₂ CHCH ₂ COCH=CHC ₆ H ₅ (20.0 g.)	C ₂ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH ₂ COCH ₂ CH(C ₂ H ₅)C ₆ H ₅ (24.6 g.); * <i>no</i> carbinol	111
(C ₆ H ₅) ₂ CHCH ₂ COCH=CHC ₆ H ₅ (40.0 g.)	C ₆ H ₅ MgBr	[(C ₆ H ₅) ₂ CHCH ₂] ₂ CO (23.2 g.); C ₆ H ₅ (C ₆ H ₅ CH=CH)[(C ₆ H ₅) ₂ CHCH ₂]COH (trace)	111
C₂₃H₂₀O₃			
(C ₆ H ₅ COCH ₂) ₂ CHC ₆ H ₄ -2-OH	C ₆ H ₅ MgBr	1,1,3-Triphenyl-3-(<i>o</i> -hydroxyphenyl)-1-propanol (?) ^{††}	572
(C ₆ H ₅ COCH ₂) ₂ CHC ₆ H ₄ -2-OH	C ₆ H ₅ MgBr	2,2,4-Triphenylchroman § [†]	572
(C ₆ H ₅ COCH ₂) ₂ CHC ₆ H ₄ -2-OH	C ₆ H ₅ MgBr	2,2-Diphenyl-4-(β, β-diphenyl-vinyl)-1,4-benzopyran ^{†**}	571
(C ₆ H ₅ COCH ₂) ₂ CHC ₆ H ₄ -2-OH	C ₆ H ₅ MgBr	1,7,7-Triphenyl-3,4-benzo-2,8-dioxabicyclo-[3.3.1] non-3-ene ^{††}	571
C₂₃H₂₁ON			
1-Benzyl-2-phenyl-3- <i>p</i> -toluylethyleneimine	C ₆ H ₅ MgBr (4 equiv.)	1-Benzyl-2,4-diphenyl-4- <i>p</i> -tolyl-4-hydroxypropyleneimine, m.p. 117° (80%)	484
1-Benzyl-2- <i>p</i> -tolyl-3-benzoylethyleneimine	C ₆ H ₅ MgBr (4 equiv.)	1-Benzyl-2- <i>p</i> -tolyl-4,4-diphenyl-4-hydroxypropyleneimine (95%)	484

* This is probably a misprint; the reported yield is obviously more than 100% of the theoretical.

† According to Geissman (571) the product tentatively so designated by Gomm and Hill (572) is in fact 1,7,7-triphenyl-3,4-benzo-2,8-dioxabicyclo[3.3.1]non-3-ene.

‡ Slow addition of Grignard reagent solution to Et₂O-ketone suspension; overnight standing.

§ 2,2,4-Triphenyl-2,3-dihydro-1,4-benzopyran, or 2,4-diphenylflavan.

† Slow addition of Grignard reagent solution to boiling C₆H₆-ketone solution; one-hour reflux; overnight standing.

‡ 2-Phenyl-4-(β, β-diphenylvinyl)flavene, or 2,2-diphenyl-4-(β, β-diphenylvinyl)-chromene.

** Addition of C₆H₆-ketone solution to ethereal Grignard reagent solution; two and one-half hours reflux.

†† Addition of Grignard reagent solution to cooled (5-10°) Et₂O-ketone suspension.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₃H₂₂O			
C ₆ H ₅ COCH(C ₆ H ₅)C ₆ H ₂ -2,4,6-(CH ₃) ₃	<i>i</i> -C ₃ H ₇ MgBr	C ₆ H ₅ CH(OH)CH(C ₆ H ₅)C ₆ H ₂ -2,4,6-(CH ₃) ₃	500
C₂₃H₂₂O₂			
CH ₃ CO(CH ₂) ₂ OC(C ₆ H ₅) ₃	1-Cyclohexenylethynyl-MgBr	"Condensation products"	97
C ₆ H ₅ CH ₂ COCH(CH ₂ C ₆ H ₅)C ₆ H ₄ -4-OCH ₃	C ₆ H ₅ CH ₂ MgCl	HO(C ₆ H ₅ CH ₂) ₂ CCH(CH ₂ C ₆ H ₅)C ₆ H ₄ -4-OCH ₃	582
C₂₃H₂₈O₂			
C ₆ H ₅ COCOC ₆ H ₂ -2,4,6-(<i>i</i> -C ₃ H ₇) ₃	CH ₃ MgI	HO(CH ₃)(C ₆ H ₅)CCOC ₆ H ₂ -2,4,6-(<i>i</i> -C ₃ H ₇) ₃	508
C₂₃H₂₈O₂N₂			
3-(4-Morpholino)-4-phenyl-4-(1,2,3,4-tetrahydro-1-quinolyl)butanone	CH ₃ MgI	"No reaction"	561
C₂₃H₂₈O₃			
4-CH ₃ OC ₆ H ₄ COCH ₂ CH[CH(CH ₂) ₅]C ₆ H ₄ -4-OCH ₃	CH ₃ MgI	HO(CH ₃)(4-CH ₃ OC ₆ H ₄)CCH ₂ CH[CH(CH ₂) ₅]-C ₆ H ₄ -4-OCH ₃	514
4-CH ₃ OC ₆ H ₄ COCH ₂ CH[CH(CH ₂) ₅]C ₆ H ₄ -4-OCH ₃	C ₂ H ₅ MgI	HO(C ₂ H ₅)(4-CH ₃ OC ₆ H ₄)CCH ₂ CH[CH(CH ₂) ₅]-C ₆ H ₄ -4-OCH ₃	514
C₂₃H₂₈O₃N₂			
α,β -Di-4-morpholinylbenzylacetophenone	CH ₃ MgI (0.50 g. Mg)	2,4-Diphenyl-3,4-di-4-morpholinyl-2-butanol (0.05 g.); intractable oil	544
C₂₃H₃₀O₅			
3-CH ₃ O-4-C ₂ H ₅ OC ₆ H ₃ CH(CH ₃)CO-(CH ₂) ₂ C ₆ H ₃ -3-OCH ₃ -4-OC ₂ H ₅	CH ₃ MgI	3-CH ₃ O-4-C ₂ H ₅ OC ₆ H ₃ CH(CH ₃)C(OH)(CH ₃)-(CH ₂) ₂ C ₆ H ₃ -3-OCH ₃ -4-OC ₂ H ₅	583

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₄H₂₂O			
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH=C(C ₆ H ₅) ₂ (5 g.)	CH ₃ MgI (1.6 g. Mg.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂ C(C ₆ H ₅) ₂ CH ₃ (82%)	538
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH=C(C ₆ H ₅) ₂	C ₂ H ₅ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂ C(C ₆ H ₅) ₂ C ₂ H ₅	538
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH=C(C ₆ H ₅) ₂ (5 g.)	C ₆ H ₅ MgBr (1.6 g. Mg.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂ C(C ₆ H ₅) ₃ (60%)	538
C₂₄H₂₄O₂			
2-o-CH ₃ OC ₆ H ₄ C ₆ H ₄ COC ₆ H-2,3,5,6- (CH ₃) ₄ (4.2 g.)	C ₆ H ₅ CH ₂ MgCl (13 g. C ₇ H ₇ Cl)	2-o-CH ₃ OC ₆ H ₄ -4-C ₆ H ₅ CH ₂ C ₆ H ₅ COC ₆ H- 2,3,5,6-(CH ₃) ₄ (0.2 g.)	515
C₂₄H₂₆ON₂			
C ₆ H ₅ COCH[C ₆ H ₄ -4-N(CH ₃) ₂] ₂	C ₆ H ₅ MgBr	HO(C ₆ H ₅) ₂ CCH[C ₆ H ₄ -4-N(CH ₃) ₂] ₂	203
C₂₄H₂₆O₂			
2-Methyl-3-mesityl-5-mesitylfuran	CH ₃ MgI (6 equiv.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ C(OH)=CHCH(t-C ₄ H ₉)CH ₂ C ₆ H ₂ -2,4,6-(CH ₃) ₃	576
C₂₄H₂₈O₂			
2-(2,4,6-Triisopropylbenzoyl)benzo- furan (25 g.)	C ₆ H ₅ MgBr (0.1 mole)	2-(2,4,6-Triisopropylbenzoyl)-3-phenyl-2,3- dihydrobenzofuran (21 g., crude)	451
C₂₄H₃₀ON₂			
3-(1-Piperidyl)-4-phenyl-4-(1,2,3,4- tetrahydro-1-quinolyl)butanone	CH ₃ MgI	"No reaction"	561
3-(1-Piperidyl)-4-phenyl-4-(1,2,3,4- tetrahydro-2-isoquinolyl)butanone	CH ₃ MgI	2-Methyl-3-(1-piperidyl)-4-phenyl-4-(1,2,3,4- tetrahydro-2-isoquinolyl)-2-butanol (14%)	561
3-(1-Piperidyl)-4-phenyl-4-(1,2,3,4- tetrahydro-2-isoquinolyl)butanone	C ₆ H ₅ MgBr	2,4-Diphenyl-3-(1-piperidyl)-4-(1,2,3,4- tetrahydro-2-isoquinolyl)-2-butanol (47%)	561

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₄H₄₀O₃			
2,5-(CH ₃ O) ₂ C ₆ H ₃ CO- <i>n</i> -C ₁₅ H ₃₁	CH ₃ MgI	2,4-(CH ₃ O) ₂ C ₆ H ₃ C(CH ₃)=CH- <i>n</i> -C ₁₄ H ₂₉ (60-70%)*	557
C₂₅H₁₈O			
(4-C ₆ H ₅ C ₆ H ₄) ₂ CO	<i>t</i> -C ₄ H ₉ MgCl	<i>t</i> -C ₄ H ₉ (4-C ₆ H ₅ C ₆ H ₄) ₂ COH (5%); [†] recovered ketone	403
(4-C ₆ H ₅ C ₆ H ₄) ₂ CO	3-ClC ₆ H ₄ MgI	3-ClC ₆ H ₄ (4-C ₆ H ₅ C ₆ H ₄) ₂ COH (quant.)	415
(4-C ₆ H ₅ C ₆ H ₄) ₂ CO (40 g.)	C ₆ H ₅ MgBr (40 g. C ₆ H ₅ Br)	C ₆ H ₅ (4-C ₆ H ₅ C ₆ H ₄) ₂ COH (35 g.)	375
(4-C ₆ H ₅ C ₆ H ₄) ₂ CO (6.7 g.)	3-CH ₃ C ₆ H ₄ MgBr (7.25 g. C ₆ H ₅ Br)	3-CH ₃ C ₆ H ₄ (4-C ₆ H ₅ C ₆ H ₄) ₂ COH (5.32 g.)	431
(4-C ₆ H ₅ C ₆ H ₄) ₂ CO	4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ (4-C ₆ H ₅ C ₆ H ₄) ₂ COH (58%)	431
(4-C ₆ H ₅ C ₆ H ₄) ₂ CO (30 g.)	1-C ₁₀ H ₇ MgBr (32 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ (4-C ₆ H ₅ C ₆ H ₄) ₂ COH (35 g., crude)	583
(4-C ₆ H ₅ C ₆ H ₄) ₂ CO	4-C ₆ H ₅ C ₆ H ₄ MgI	(4-C ₆ H ₅ C ₆ H ₄) ₃ COH	375
C₂₅H₂₄O₂			
C ₆ H ₅ CH ₂ COCH ₂ CH(CH ₂ C ₆ H ₅)-COCH ₂ C ₆ H ₅ (0.6 g.)	C ₆ H ₅ MgBr (1.0 g. C ₆ H ₅ Br)	HO(C ₆ H ₅)(C ₆ H ₅ CH ₂)CCCH ₂ CH(CH ₂ C ₆ H ₅)-COCH ₂ C ₆ H ₅ (250 mg.)	495
C₂₅H₃₈O₃			
3-Acetoxy-20-iso-5-ternorcholenyl methyl ketone (23.2 g.)	CH ₃ MgBr (85 g. CH ₃ Br)	3-Hydroxy-20-iso-5-ternorcholenyldimethyl-methanol (17.1 g.)	577
C₂₅H₄₀O₃			
3-Acetoxy-20-ternor <i>allo</i> cholanyl methyl ketone (23.2 g.)	CH ₃ MgBr (85 g. CH ₃ Br)	3-Hydroxy-20-ternor <i>allo</i> cholanyldimethyl-methanol (15.2 g.)	577
3-Acetoxy-20-isoternor <i>allo</i> cholanyl methyl ketone (23.2 g.)	CH ₃ MgBr (85 g. CH ₃ Br)	3-Hydroxy-20-isoternor <i>allo</i> cholanyldimethyl-methanol (21.3 g.)	577

*The figures recorded represent the range of yields reported for a series of reactions studied.

[†]"Boiling the solution for many hours with and without the addition of benzene, toluene, or xylene, or even heating to 150° in ether in a sealed tube for eight hours failed to increase the yield of carbinol to more than 10 percent...."

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₆H₁₆O₂Cl₂ [2-(2-ClC ₆ H ₄ CO)C ₆ H ₄ —] ₂	C ₂ H ₅ MgBr	{2-[2-ClC ₆ H ₄ C(OH)(C ₂ H ₅)]C ₆ H ₄ —} ₂ (23%)	584
C₂₆H₁₈O 9-(2-Benzoylphenyl)fluorene	C ₆ H ₅ MgBr	2-(9-Fluorenyl)triphenylmethanol	585
C₂₆H₁₈O₂ (2-C ₆ H ₅ COC ₆ H ₄ —) ₂ (4-C ₆ H ₅ COC ₆ H ₄ —) ₂ (9 g.)	C ₂ H ₅ MgBr C ₆ H ₅ MgBr (12 g. C ₆ H ₅ Br)	[2-HO(C ₂ H ₅)(C ₆ H ₅)CC ₆ H ₄ —] ₂ (46%) [4-HO(C ₆ H ₅) ₂ CC ₆ H ₄ —] ₂ (10 g.)	584 578
C₂₆H₂₀O C ₆ H ₅ COC(C ₆ H ₅) ₃ C ₆ H ₅ COC(C ₆ H ₅) ₃ (20 g.) C ₆ H ₅ COC ₆ H ₄ -4-CH(C ₆ H ₅) ₂ (7 g.)	<i>n</i> -C ₃ H ₇ MgBr C ₆ H ₅ MgI (100 g. C ₆ H ₅ I) 4-BrC ₆ H ₄ MgBr (13 g. C ₆ H ₄ Br ₂)	C ₆ H ₅ [(C ₆ H ₅) ₃ C]CHOH (C ₆ H ₅) ₃ C(C ₆ H ₅) ₂ COH (10 g., crude) 4-BrC ₆ H ₄ (C ₆ H ₅)[4-(C ₆ H ₅) ₂ CHC ₆ H ₄]COH (converted to bromide, 5 g.)	587 589 588
C ₆ H ₅ COC ₆ H ₄ -4-CH(C ₆ H ₅) ₂ C ₆ H ₅ COC ₆ H ₄ -4-CH(C ₆ H ₅) ₂ (10 g.)	C ₆ H ₅ MgBr (18 g. C ₆ H ₅ Br) 4-CH ₃ C ₆ H ₄ MgBr (10 g. C ₆ H ₅ Br)	4-(C ₆ H ₅) ₂ CHC ₆ H ₄ (C ₆ H ₅) ₂ COH (22 g., crude) C ₆ H ₅ (4-CH ₃ C ₆ H ₄)[4-(C ₆ H ₅) ₂ CHC ₆ H ₄]COH (converted to bromide, 10.5 g.)	588 588
C ₆ H ₅ COC ₆ H ₄ -4-CH(C ₆ H ₅) ₂ (10 g.)	1-C ₁₀ H ₇ MgBr (13.5 g. C ₆ H ₅ Br)	C ₆ H ₅ (1-C ₁₀ H ₇)[4-(C ₆ H ₅) ₂ CHC ₆ H ₄]COH (converted to chloride, 12 g.)	588
4-C ₆ H ₅ C ₆ H ₄ COCH ₂ C ₆ H ₄ -4-C ₆ H ₅ 4-C ₆ H ₅ C ₆ H ₄ COCH ₂ C ₆ H ₄ -4-C ₆ H ₅	C ₆ H ₅ MgBr 1-C ₁₀ H ₇ MgBr	C ₆ H ₅ (4-C ₆ H ₅ C ₆ H ₄)(4-C ₆ H ₅ C ₆ H ₄ CH ₂)COH 1-C ₁₀ H ₇ (4-C ₆ H ₅ C ₆ H ₄)(4-C ₆ H ₅ C ₆ H ₄ CH ₂)COH	586 586
C₂₆H₂₀O₂ C ₆ H ₅ COC(C ₆ H ₅) ₂ OC ₆ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ O(C ₆ H ₅) ₂ CC(C ₆ H ₅) ₂ OH (88%)	570
C₂₆H₂₇ON C ₆ H ₅ COCH[N(CH ₂) ₅]CH(C ₆ H ₅) ₂ (1.0 g.)	C ₆ H ₅ MgBr (0.2 g. Mg)	HO(C ₆ H ₅) ₂ CCH[N(CH ₂) ₅]CH(C ₆ H ₅) ₂	559

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₆H₃₂O₂			
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH= C(<i>t</i> -C ₄ H ₉)COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (0.32 g.)	C ₆ H ₅ MgBr (4 equiv.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH(C ₆ H ₅)- CH(<i>t</i> -C ₄ H ₉)COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (0.12 g.)*	590
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH= C(<i>t</i> -C ₄ H ₉)COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (1.15 g.)	C ₆ H ₅ MgBr (4 equiv.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC(C ₆ H ₅)= C(<i>t</i> -C ₄ H ₉)COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (0.96 g.)†	590
C₂₆H₃₃O₂Br			
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCHBrCH- (<i>t</i> -C ₄ H ₉)COC ₆ H ₂ -2,4,6-(CH ₃) ₃	CH ₃ MgX‡ (2 equiv.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ C(OH)=CHCH- (<i>t</i> -C ₄ H ₉)COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (ca. quant.)	576
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCHBrCH- (<i>t</i> -C ₄ H ₉)COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (0.5 g.)	<i>t</i> -C ₄ H ₉ MgCl	2,4,6-(CH ₃) ₃ C ₆ H ₂ C(OH)= CHCH(<i>t</i> -C ₄ H ₉)COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (0.24 g.)	576
C₂₆H₄₄O₃			
2,5-(CH ₃ O) ₂ C ₆ H ₃ CO- <i>n</i> -C ₁₇ H ₃₅	CH ₃ MgI	2,5-(CH ₃ O) ₂ C ₆ H ₃ C(CH ₃)=CH- <i>n</i> - C ₁₆ H ₃₃ (60-70%)§	557
C₂₇H₂₀O			
C ₆ H ₅ COC(C ₆ H ₅)=C(C ₆ H ₅) ₂	CH ₃ MgI (4 equiv.)	HO(CH ₃)(C ₆ H ₅)CC(C ₆ H ₅)=C(C ₆ H ₅) ₂ (53.6-63.4%)	591

* Addition of ketone to Grignard reagent solution at room temperature; ten minutes standing.

† Addition of ketone to Grignard reagent solution at 0°; fifteen minutes standing; treatment with EtOH-Br₂ at -10°.

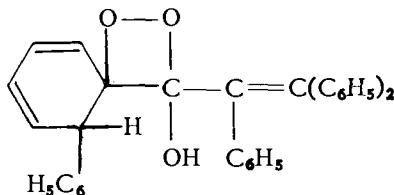
‡ X = Br, I.

§ The figure here recorded represents the range of yields reported for a series of reactions studied.

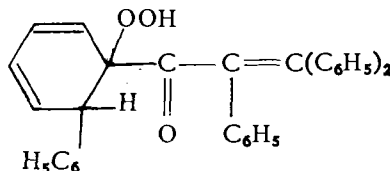
TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₇H₂₀O (<i>cont.</i>)			
C ₆ H ₅ COC(C ₆ H ₅)=C(C ₆ H ₅) ₂	C ₆ H ₅ MgBr (4 equiv.)	"Enol peroxide" (37.3%);* HO(C ₆ H ₅) ₂ CC(C ₆ H ₅)=C(C ₆ H ₅) ₂ (31.9%)	591
9-Phenyl-10-benzoyl-9,10-dihydro-anthracene (3.5 g.)	C ₆ H ₅ MgBr	Recovered ketone (1.2 g.); phenylanthra- pnone (0.7 g.)	565
C₂₇H₂₁OBr			
C ₆ H ₅ COCBr(C ₆ H ₅)CH(C ₆ H ₅) ₂	C ₆ H ₅ MgBr	C ₆ H ₅ COCH(C ₆ H ₅)CH(C ₆ H ₅) ₂ ; "1-hydroxy- 1,2,3,3-tetraphenylpropene peroxide" [†]	437

*Kohler (591, etc.) formulated his "enol peroxides" as compounds containing a 2-oxygen 2-carbon four-membered ring—in this instance,



Rigaudy, *Compt. rend.*, 226, 1993-5 (1948), has pointed out the probable instability of such structures, has cited the similarity in chemical properties between Kohler's "enol peroxides" and known hydroperoxides, and has shown that the ultraviolet absorption spectrum of one of Kohler's "enol peroxides" bears evidence of the presence of a carbonyl group and is closely similar to those of analogous ketones but quite different from that of an analogous carbinol. The more probable formulation would seem to be:



[†]Probably the hydroperoxide, C₆H₅(C₆H₅CO)[(C₆H₅)₂CH]COOH.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₂₇H₂₂O			
C ₆ H ₅ COCH(C ₆ H ₅)CH(C ₆ H ₅) ₂ (15 g.)	CH ₃ MgI (4 g. Mg)	CH ₃ (C ₆ H ₅)[(C ₆ H ₅) ₂ CHCH(C ₆ H ₅)]COH (> 12.5 g.)	591
C ₆ H ₅ COCH(C ₆ H ₅)CH(C ₆ H ₅) ₂ (5 g.)	C ₆ H ₅ MgBr (1.4 g. Mg)	HO(C ₆ H ₅) ₂ CCH(C ₆ H ₅)CH(C ₆ H ₅) ₂ (33%)	591
C₂₈H₁₈O₂			
2- <i>p</i> -Benzoylphenyl-3-phenylindone	C ₆ H ₅ MgBr (excess)	1,3-Diphenyl-2-(<i>p</i> - α -hydroxybenzhydryl-phenyl)indanol	592
C₂₈H₂₀O₂			
C ₆ H ₅ COC(C ₆ H ₅)=C(C ₆ H ₅)COC ₆ H ₅ (15 g.)	C ₆ H ₅ MgBr (35 g. C ₆ H ₅ Br)	HO(C ₆ H ₅) ₂ CC(C ₆ H ₅)=C(C ₆ H ₅)COC ₆ H ₅ (70-90%)	602
2-Benzoyl-3,4,5-triphenylfuran	C ₆ H ₅ MgBr	Diphenyl-2-(3,4,5-triphenylfuryl)methanol (70%)	593
C₂₈H₂₂O₂			
[2-(3-CH ₃ C ₆ H ₄ CO)C ₆ H ₄ —] ₂	C ₂ H ₅ MgBr	{2-[HO(C ₂ H ₅)(3-CH ₃ C ₆ H ₄)C]C ₆ H ₄ —} ₂ (35%)	584
C₂₈H₂₈O₂			
2,4,6-(CH ₃) ₃ C ₆ H ₂ COC(C ₆ H ₅)=CHCOC ₆ H ₂ -2,4,6-(CH ₃) ₃	<i>t</i> -C ₄ H ₉ MgCl	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC(<i>t</i> -C ₄ H ₉)(C ₆ H ₅)CH ₂ CO-C ₆ H ₂ -2,4,6-(CH ₃) ₃	590
C₂₈H₄₈O			
C ₆ H ₅ CO- <i>n</i> -C ₂₁ H ₄₃ (55 g.)	<i>n</i> -C ₄ H ₉ MgCl	<i>n</i> -C ₄ H ₉ (C ₆ H ₅)(<i>n</i> -C ₂₁ H ₄₃)COH (62 g., crude)	594
C₂₉H₂₄O			
C ₆ H ₅ COCH(C ₆ H ₅)CH(C ₆ H ₅)CH=CHC ₆ H ₅	C ₆ H ₅ MgBr (3 equiv.)	HO(C ₆ H ₅) ₂ CCH(C ₆ H ₅)CH(C ₆ H ₅)CH=CHC ₆ H ₅	595

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₉H₂₄O₂ 2,2-Diphenyl-4-phenacylchroman*	C ₆ H ₅ MgBr	2,2-Diphenyl-4-(β -hydroxy- β,β -diphenyl-ethyl)chroman	571
C₂₉H₃₂ON₂ α -Piperidyl- β -phenyl- β -(1,2,3,4-tetrahydroquinolyl)propiophenone	CH ₃ MgI	2,4-Diphenyl-3-piperidyl-4-(1,2,3,4-tetrahydroquinolyl)-2-butanol (20%)	561
C₃₀H₁₆O₂Br₂ 1,6-Dibenzoyl-3,6-dibromopyrene [†] (15 g.)	C ₆ H ₅ MgBr (36 g. C ₆ H ₅ Br)	1,6-Bis(diphenylhydroxymethyl)-3,8-dibromopyrene [†] (14.5 g.)	579
1,8-Dibenzoyl-3,6-dibromopyrene [†] (17 g.)	C ₆ H ₅ MgBr (36 g. C ₆ H ₅ Br)	1,8-Bis(diphenylhydroxymethyl)-3,6-dibromopyrene [†] (12 g.)	579
C₃₀H₁₈O₂ 1,6-Dibenzoylpyrene [†] (16 g.)	C ₆ H ₅ MgBr (36 g. C ₆ H ₅ Br)	1,6-Bis(diphenylhydroxymethyl)pyrene [†] (17 g.)	579
1,8-Dibenzoylpyrene [†] (16 g.)	C ₆ H ₅ MgBr (36 g. C ₆ H ₅ Br)	1,8-Bis(diphenylhydroxymethyl)pyrene [†] (18 g.)	579
C₃₀H₂₀O₃ C ₆ H ₅ COC \equiv CC(COC ₆ H ₅) ₂ C ₆ H ₅	CH ₃ MgBr	HO(CH ₃)(C ₆ H ₅)CC \equiv CC(COC ₆ H ₅) ₂ C ₆ H ₅	85
C₃₀H₂₅ON 2,4,6-Triphenyl-3-benzoyl-2,3,4,5-tetrahydropyridine (0.16 g., 0.00145 mole)	CH ₃ MgCl (excess)	2,4,6-Triphenyl-3-(1-hydroxy-1-phenyl-ethyl)-2,3,4,5-tetrahydropyridine (97%)	596

*2,2-Diphenyl-4-phenacyl-2,3-dihydro-1,4-benzopyran.

[†]The numbering here employed is that of the "Ring Index" rather than that of the authors cited.

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃₀H₂₅ON (<i>cont.</i>)			
2,4,6-Triphenyl-3-benzoyl-2,3,4,5-tetrahydropyridine (2.0 g., 0.0048 mole)	C ₆ H ₅ MgBr (0.012 mole)	2,4,6-Triphenyl-3-(α -hydroxy-benzhydryl)-2,3,4,5-tetrahydropyridine (1.69 g., 0.0034 mole, 71%)	596
C₃₀H₂₆O₄			
[2-(4-C ₂ H ₅ OC ₆ H ₄ CO)C ₆ H ₄ —] ₂	C ₂ H ₅ MgBr	{2-[HO(C ₂ H ₅)(4-C ₂ H ₅ OC ₆ H ₄ C]C ₆ H ₄ —} ₂ (33%)	584
C₃₀H₃₀O₂			
2-Methyl-3-mesityl-4-phenyl-5-mesitylfuran (9.7 g.)	CH ₃ MgI (5 equiv.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCII(C ₆ H ₅)CH(<i>t</i> -C ₄ H ₉)-COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (5.85 g.)	590
C₃₁H₆₂O			
(<i>n</i> -C ₁₅ H ₃₁) ₂ CO	CH ₃ MgBr (3 equiv.)	CH ₃ (C ₁₅ H ₃₁) ₂ COH	598
(<i>n</i> -C ₁₅ H ₃₁) ₂ CO	C ₂ H ₅ MgBr (3 equiv.)	C ₂ H ₅ (C ₁₅ H ₃₁) ₂ COH	598
(<i>n</i> -C ₁₅ H ₃₁) ₂ CO	<i>n</i> -C ₄ H ₉ MgBr (3 equiv.)	<i>n</i> -C ₄ H ₉ (C ₁₅ H ₃₁) ₂ COH (<i>ca.</i> 80%); recovered ketone; (C ₁₅ H ₃₁) ₂ CHOH; C ₃₁ H ₆₄	598
(<i>n</i> -C ₁₅ H ₃₁) ₂ CO (63 g.)	<i>n</i> -C ₁₆ H ₃₃ Br (26 g.) + Mg (3.6 g.)	<i>n</i> -C ₁₆ H ₃₃ (<i>n</i> -C ₁₅ H ₃₁) ₂ COH (3.2 g.)	598
C₃₂H₂₂O			
5-Benzoyl-9,9-diphenylfluorene	C ₆ H ₅ MgBr	Diphenyl-9,9-diphenyl-5-fluorenylmethanol	597
C₃₂H₃₈O₂			
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH(C ₆ H ₅)CH(<i>t</i> -C ₄ H ₉)COC ₆ H ₂ -2,4,6-(CH ₃) ₃	CH ₃ MgI	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC(C ₆ H ₅)=C(<i>t</i> -C ₄ H ₉)-COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (40%)	590
C₃₂H₅₀O			
2-C ₁₀ H ₇ CO- <i>n</i> -C ₂₁ H ₄₃	<i>n</i> -C ₄ H ₉ MgCl	<i>n</i> -C ₄ H ₉ (2-C ₁₀ H ₇)(<i>n</i> -C ₂₁ H ₄₃)COH	594

TABLE VI-XVIII (Continued)

<u>Ketonic Comp'd</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₃₂H₅₄O <i>n</i> -Heneicosyl 6-(1,2,3,4-tetrahydro- naphthyl) ketone	<i>n</i> -C ₄ H ₉ MgCl	<i>n</i> -C ₄ H ₉ (C ₁₀ H ₁₁)(<i>n</i> -C ₂₁ H ₄₃)COH	594
C₃₂H₅₄O 4-C ₆ H ₅ C ₆ H ₄ CO- <i>n</i> -C ₂₁ H ₄₃	<i>n</i> -C ₄ H ₉ MgCl	<i>n</i> -C ₄ H ₉ (4-C ₆ H ₅ C ₆ H ₄)(<i>n</i> -C ₂₁ H ₄₃)COH	594
C₃₈H₂₆O₂ [2-(4-C ₆ H ₅ C ₆ H ₄ CO)C ₆ H ₄ —] ₂	C ₂ H ₅ MgBr	{ 2-[HO(C ₂ H ₅)(4-C ₆ H ₅ C ₆ H ₄)C]C ₆ H ₄ — } ₂	584

REFERENCES FOR TABLE VI-XVIII

- (1) Dashkevich, *J. Gen. Chem. (U.S.S.R.)*, 18, 205-8 (1948); *Chem. Abstr.*, 42, 7244 (1948).
- (2) Dashkevich, *J. Gen. Chem. (U.S.S.R.)*, 8, 779-81 (1938); *Chem. Abstr.*, 33, 1293 (1939).
- (3) Henry, *Bull. soc. chim. Belg.*, 20, 152-6 (1906).
- (4) Shtukin, *J. Gen. Chem. (U.S.S.R.)*, 10, 77-81 (1940); *Chem. Abstr.*, 34, 4725 (1940).
- (5) Christie, McKenzie, and Ritchie, *J. Chem. Soc.*, 1935, 153-5.
- (6) Huston, Jackson, and Spero, *J. Am. Chem. Soc.*, 63, 1459-60 (1941).
- (7) Henry, *Compt. rend.*, 145, 21-5 (1907); *Chem. Zentr.*, 1907,II, 889.
- (8) Tiffeneau, *Compt. rend.*, 134, 774-5 (1902); *Chem. Zentr.*, 1902,I, 1092.
- (9) Fourneau and Tiffeneau, *Compt. rend.*, 145, 437-9 (1907); *Chem. Zentr.*, 1907,II, 1320.
- (10) Kyriakides, *J. Am. Chem. Soc.*, 36, 657-63 (1914).
- (11) Kinney and Spliethoff, *J. Org. Chem.*, 14, 71-8 (1949).
- (12) Tiffeneau, *Compt. rend.*, 137, 989-91 (1903); *J. Chem. Soc.*, 86,I, 63 (1904).
- (13) Tiffeneau, *Bull. soc. chim.*, [3], 29, 1156-8 (1903).
- (14) Temnikova and Veksler, *J. Gen. Chem. (U.S.S.R.)*, 19, 1318-23 (1949); *Chem. Abstr.*, 44, 1056 (1950).
- (15) Tiffeneau and Deux, *Compt. rend.*, 213, 753-8 (1941); *Chem. Abstr.*, 37, 4049 (1943).
- (16) Bradsher and Tess, *J. Am. Chem. Soc.*, 61, 2184-5 (1939).
- (17) Fréon, *Ann. chim.*, [11], 11, 435-518 (1939).
- (18) Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).
- (19) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 34, 242-4 (1902); *Bull. soc. chim.*, [3], 30, 210 (1903).
- (20) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 36, 1545-51 (1904); *Bull. soc. chim.*, [3], 36, 177 (1906).
- (21) Dupont, *Ann. chim.*, [8], 30, 485-587 (1913).
- (22) Zal'kind and Labuzov, *J. Gen. Chem. (U.S.S.R.)*, 9, 1525-32 (1939); *Chem. Abstr.*, 34, 2788 (1940).
- (23) Salkind and Teterin, *Ber.*, 66B, 321-5 (1933).
- (24) Meisenheimer, *Ann.*, 442, 180-210 (1925).
- (25) Henze, Allen, and Leslie, *J. Org. Chem.*, 7, 326-35 (1942).
- (26) Jaworski, *J. Russ. Phys.-Chem. Soc.*, 40, 782-7 (1908); *Chem. Zentr.*, 1908,II, 1412.
- (27) Jaworski, *J. Russ. Phys.-Chem. Soc.*, 40, 1746-8 (1909); *Chem. Zentr.*, 1909,I, 856.
- (28) Jaworski, *Ber.*, 42, 435-8 (1909).
- (29) Bacon and Farmer, *J. Chem. Soc.*, 1937, 1065-77.
- (30) Ou Kuin-Houo, *Ann. chim.*, [11], 13, 175-241 (1940).
- (31) Wibaut, Hoog, Langedijk, Overhoff, and Smittenberg, *Rec. trav. chim.*, 58, 329-77 (1939).
- (32) Deschamps, *J. Am. Chem. Soc.*, 42, 2670-3 (1920).
- (33) Whitmore and Badertsher, *J. Am. Chem. Soc.*, 55, 1559-67 (1933).
- (34) Schreiner, *J. prakt. Chem.*, [2], 82, 292-6 (1910).
- (35) Norton and Hass, *J. Am. Chem. Soc.*, 58, 2147-50 (1936).
- (36) Iotsitch, Breitfous, Roudolf, Stassévitch, Elmanovitch, Kondyref, and Fomine, *J. Russ. Phys.-Chem. Soc.*, 39, 652-7 (1907); *Bull. soc. chim.*, [4], 6, 98-100 (1909).
- (37) Stas, *Bull. soc. chim. Belg.*, 35, 379-86 (1926).

- (38) Carothers and Berchet, *J. Am. Chem. Soc.*, 55, 1094-6 (1933).
- (39) Zal'kind and Pletz, *Trans. Leningrad Chem.-Tech. Inst.*, 1, 57-60 (1934); *Chem. Abstr.*, 29, 2908 (1935).
- (40) Nazarov and Elizarova, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1940, 189-94; *Chem. Abstr.*, 36, 741 (1942).
- (41) Thomas, *Bull. soc. chim.*, [4], 5, 730-6 (1909).
- (42) Dupont, *Compt. rend.*, 148, 1522-4 (1909); *Chem. Abstr.*, 3, 2674 (1909).
- (43) Shchukina and Rubstov, *J. Gen. Chem. (U.S.S.R.)*, 18, 1645-52 (1948); *Chem. Abstr.*, 43, 2570 (1949).
- (44) Tamele, Ott, Marple, and Hearne, *Ind. Eng. Chem.*, 33, 115-20 (1941).
- (45) Roberts and Young, *J. Am. Chem. Soc.*, 67, 148-50 (1945).
- (46) Edgar, Calingaert, and Marker, *J. Am. Chem. Soc.*, 51, 1483-91 (1929).
- (47) Church, Whitmore, and McGrew, *J. Am. Chem. Soc.*, 56, 176-84 (1934).
- (48) Petrov and Kurbskiĭ, *J. Gen. Chem. (U.S.S.R.)*, 14, 492-4 (1944); *Chem. Abstr.*, 39, 4600 (1945).
- (49) Pierotti and Stewart, *J. Am. Chem. Soc.*, 59, 1773-5 (1937).
- (50) Konowalow, *J. Russ. Phys.-Chem. Soc.*, 37, 910-1 (1906); *Chem. Zentr.*, 1906,I, 330.
- (51) Willcox and Brunel, *J. Am. Chem. Soc.*, 38, 1821-41 (1916).
- (52) Henry, *Bull. acad. roy. Belg.*, 1906, 352-63; *Chem. Zentr.*, 1906,II, 748.
- (53) Elliott and Linstead, *J. Chem. Soc.*, 1938, 660-5.
- (54) Meyer and Tuot, *Compt. rend.*, 196, 1231-3 (1933).
- (55) Halse, *J. prakt. Chem.*, [2], 89, 451-65 (1914).
- (56) Tissier and Grignard, *Compt. rend.*, 132, 1182-4 (1901); *Chem. Zentr.*, 1901,I, 1357.
- (57) Bergmann, Taubadel, and Weiss, *Ber.*, 64B, 1493-501 (1931).
- (58) Sabatier and Mailhe, *Compt. rend.*, 139, 343-6 (1904); *J. Chem. Soc.*, 86,I, 809 (1904).
- (59) Sabatier and Mailhe, *Ann. chim.*, [8], 10, 527-74 (1907).
- (60) Sontag, *Ann. chim.*, [11], 1, 359-438 (1934).
- (61) Grignard, *Compt. rend.*, 130, 1322-4 (1900); *J. Chem. Soc.*, 78,I, 382 (1900).
- (62) Sabatier and Murat, *Compt. rend.*, 156, 184-7 (1913); *Chem. Abstr.*, 7, 1485 (1913).
- (63) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 36, 8-9 (1904); *Bull. soc. chim.*, [3], 34, 204 (1905).
- (64) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 34, 100-2 (1902); *Bull. soc. chim.*, [3], 28, 922 (1902).
- (65) Willemart, *Ann. chim.*, [10], 12, 345-422 (1929).
- (66) Jacobs, Cramer, and Weiss, *J. Am. Chem. Soc.*, 62, 1849-54 (1940).
- (67) Lepin, *J. Russ. Phys.-Chem. Soc.*, 44, 1190-6 (1912); *Chem. Zentr.*, 1912,II, 2080.
- (68) Bogert and Davidson, *J. Am. Chem. Soc.*, 56, 185-90 (1934).
- (69) Courtot, *Ann. chim.*, [9], 4, 58-136 (1915).
- (70) Oddo and Perotti, *Gazz. chim. ital.*, 60, 13-21 (1930); *Chem. Zentr.*, 1930,I, 3051.
- (71) Bogert, Davidson, Appelbaum, *J. Am. Chem. Soc.*, 56, 959-63 (1934).
- (72) Shurakowski, *J. Russ. Phys.-Chem. Soc.*, 41, 1687-94 (1910); *Chem. Zentr.*, 1910,I, 1144.
- (73) von Braun and Kirschbaum, *Ber.*, 52B, 1725-30 (1919).
- (74) Malmgren, *Ber.*, 35, 3910-2 (1902).
- (75) Malmgren, *Ber.*, 36, 2608-42 (1903).
- (76) Clément and Savard, *Compt. rend.*, 204, 1742-3 (1937); *Chem. Abstr.*, 31, 7044 (1937).

- (77) Clément, *Ann. chim.*, [11], 13, 243-316 (1940).
- (78) Savard and Hösögüt, *Rev. faculté sci. univ. Istanbul*, [N.S.], 3, 164-73 (1938); *Chem. Abstr.*, 32, 5795 (1938).
- (79) Smith and Miller, *J. Am. Chem. Soc.*, 64, 440-5 (1942).
- (80) Smith and Miller, U. S. Patent 2,372,132, March 20, 1945; *Chem. Abstr.*, 39, P4894 (1945).
- (81) Schmidlin and Hodgson, *Ber.*, 41, 430-7 (1907).
- (82) Kling, *Bull. soc. chim.*, [3], 31, 16-9 (1904).
- (83) Cymerman, Heilbron, and Jones, *J. Chem. Soc.*, 1944, 144-7.
- (84) Milas, Grossi, Penner, and Kahn, *J. Am. Chem. Soc.*, 70, 1292 (1948).
- (85) Kleinfeller, *Ber.*, 72B, 249-56 (1939).
- (86) Yushchenko, *Mem. Inst. Chem. Acad. Sci. Ukrain. S.S.S.R.*, 5, No. 1, 101-11 (1938); *Chem. Abstr.*, 32, 7894 (1938).
- (87) Grignard and Vignon, *Compt. rend.*, 144, 1358-60 (1907); *Chem. Zentr.*, 1907,II, 681.
- (88) Backer, Stevens, and van der Bij, *Rec. trav. chim.*, 59, 1141-55 (1940).
- (89) Deakin and Wilsmore, *J. Chem. Soc.*, 97, 1968-78 (1910).
- (90) Diels and ter Meer, *Ber.*, 42, 1940-5 (1909).
- (91) Campbell, Campbell, and Eby, *J. Am. Chem. Soc.*, 60, 2882-4 (1938).
- (92) Cottle and Powell, *J. Am. Chem. Soc.*, 58, 2267-72 (1936).
- (93) Pariselle and Simon, *Compt. rend.*, 173, 86-9 (1921).
- (94) Thompson and Margnetti, *J. Am. Chem. Soc.*, 64, 573-6 (1942).
- (95) Milas and McAlevy, *J. Am. Chem. Soc.*, 57, 580-3 (1935).
- (96) Dubois, *Compt. rend.*, 224, 1018-20 (1947); *Chem. Abstr.*, 43, 5004 (1949).
- (97) Sobotka and Chanley, *J. Am. Chem. Soc.*, 70, 3914-8 (1948).
- (98) van Risseghem, *Bull. soc. chim. Belg.*, 39, 369-73 (1930).
- (99) Whitmore and Woodburn, *J. Am. Chem. Soc.*, 55, 361-5 (1933).
- (100) Davies, Dixon, and Jones, *J. Chem. Soc.*, 1930, 468-73.
- (101) Konowaloff, *J. Russ. Phys.-Chem. Soc.*, 36, 228-32 (1904); *Chem. Zentr.*, 1904,I, 1496.
- (102) Konowalow, Miller, and Timtschenko, *J. Russ. Phys.-Chem. Soc.*, 38, 447-8 (1906); *Chem. Zentr.*, 1906,II, 311.
- (103) Thompson, Burr, and Shaw, *J. Am. Chem. Soc.*, 63, 186-8 (1941).
- (104) Davies and Kipping, *J. Chem. Soc.*, 99, 296-301 (1911).
- (105) Rupe and Bürgin, *Ber.*, 44, 1218-25 (1911).
- (106) Nightingale and Shanholtzer, *J. Org. Chem.*, 7, 6-14 (1942).
- (107) Lemaire, *Bull. acad. roy. Belg.*, 1909, 83-159; *Chem. Zentr.*, 1909,I, 1982.
- (108) Whitby and Gallay, *Can. J. Research*, 6, 280-91 (1932); *Chem. Abstr.*, 26, 3479 (1932).
- (109) Gry, *Bull. soc. chim.*, [4], 1, 1042 (1907).
- (110) Gry, *Bull. soc. chim.*, [4], 3, 377-8 (1908).
- (111) Kohler, *Am. Chem. J.*, 38, 511-61 (1907).
- (112) Stevens, *J. Am. Chem. Soc.*, 57, 1112-7 (1934).
- (113) Zelinsky, *Ber.*, 34, 2877-84 (1901).
- (114) Bruylants, *Bull. acad. roy. Belg.*, 1908, 1011-84; *Chem. Zentr.*, 1909,I, 1859.
- (115) Bruylants, *Bull. soc. chim. Belg.*, 36, 153-64 (1927).
- (116) Khaletskii, *J. Gen. Chem. (U.S.S.R.)*, 11, 319-23 (1941); *Chem. Abstr.*, 35, 5853 (1941).
- (117) Maire, *Bull. soc. chim.*, [4], 3, 280-6 (1908).
- (118) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 35, 1269-75 (1903); *Bull. soc. chim.*, [3], 34, 181 (1905).

- (119) Lapkin and Golovkova, *J. Gen. Chem.* (U.S.S.R.), 18, 485-94 (1948); *Chem. Abstr.*, 42, 7273 (1948).
- (120) Greenburg and Aston, *J. Am. Chem. Soc.*, 62, 3135 (1940).
- (121) Whitmore and Evers, *J. Am. Chem. Soc.*, 55, 812-6 (1933).
- (122) Pétroff, Karasseff, and Tschelzowa, *Bull. soc. chim.*, [5], 3, 169-76 (1936).
- (123) Malenok, *J. Gen. Chem.* (U.S.S.R.), 9, 1947-52 (1939); *Chem. Abstr.*, 34, 4385 (1940).
- (124) Whitmore and Block, *J. Am. Chem. Soc.*, 64, 1619-21 (1942).
- (125) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 38, 656-9 (1906); *Bull. soc. chim.*, [4], 4, 1203 (1906).
- (126) Clarke, *J. Am. Chem. Soc.*, 33, 520-31 (1911).
- (127) Ivanoff and Spassoff, *Bull. soc. chim.*, [5], 2, 1435-8 (1935).
- (128) Whitmore and Southgate, *J. Am. Chem. Soc.*, 60, 2571-3 (1939).
- (129) Clarke and Riegel, *J. Am. Chem. Soc.*, 34, 674-9 (1912).
- (130) Nazarov, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1940, 195-202; *Chem. Abstr.*, 36, 742 (1942).
- (131) Gauthier, *Compt. rend.*, 152, 1100-2 (1911); *Chem. Zentr.*, 1911,1, 1809.
- (132) Blicke and Tsao, *J. Am. Chem. Soc.*, 66, 1645-8 (1944).
- (133) Levina, Faïnzil'berg, and Shusherina, *J. Gen. Chem.* (U.S.S.R.), 18, 1775-80 (1948); *Chem. Abstr.*, 43, 3344 (1949).
- (134) Colonge and Lagier, *Bull. soc. chim. France*, 1949, 15-7.
- (135) Harries, *Ann.*, 343, 311-74 (1905).
- (136) Polgar and Robinson, *J. Chem. Soc.*, 1945, 389-95.
- (137) Dupont and Menut, *Bull. soc. chim.*, [5], 6, 1215-20 (1939).
- (138) von Fellenberg, *Ber.*, 37, 3578-81 (1904).
- (139) Pastereau and Bernard, *Compt. rend.*, 177, 327-9 (1923).
- (140) Esafov, *J. Gen. Chem.* (U.S.S.R.), 9, 467-70 (1939); *Chem. Abstr.*, 33, 9282 (1939).
- (141) Esafov, *J. Gen. Chem.* (U.S.S.R.), 14, 84-7 (1944); *Chem. Abstr.*, 39, 905 (1945).
- (142) Bodroux and Taboury, *Bull. soc. chim.*, [4], 5, 812-4 (1909).
- (143) Knorr, German Patent 544,388, Jan. 28, 1932; *Friedländer*, 18, 180-4 (1933).
- (144) Petrov, Lapteva, and Pchelkina, *J. Gen. Chem.* (U.S.S.R.), 14, 495-7 (1944); *Chem. Abstr.*, 39, 4598 (1945).
- (145) Esafov and Smirnov, *J. Gen. Chem.* (U.S.S.R.), 10, 1535-8 (1940); *Chem. Abstr.*, 35, 2855 (1941).
- (146) Klages, *Ber.*, 37, 2301-17 (1904).
- (147) Reynolds, *Am. Chem. J.*, 44, 305-31 (1910).
- (148) von Fellenberg, *Ber.*, 39, 2064-6 (1906).
- (149) Ivanoff, Mihova, and Christova, *Bull. soc. chim.*, [4], 51, 1321-5 (1932).
- (150) Colonge, *Bull. soc. chim.*, [5], 2, 754-61 (1935).
- (151) Grignard, *Ann. chim.*, [7], 27, 548-74 (1902).
- (152) Grignard, *Compt. rend.*, 134, 849-51 (1902); *Chem. Zentr.*, 1902,1, 1197.
- (153) Benary, *Ber.*, 64B, 2543-5 (1931).
- (154) Pastereau and Bernard, *Compt. rend.*, 174, 1555-7 (1922).
- (155) Pastereau and Bernard, *Compt. rend.*, 176, 1400-2 (1923).
- (156) Clarke, *J. Am. Chem. Soc.*, 31, 585-90 (1909).
- (157) Konowaloff, *J. Russ. Phys.-Chem. Soc.*, 34, 26-31 (1902); *Chem. Zentr.*, 1902,1, 1271.
- (158) Clarke, *J. Am. Chem. Soc.*, 34, 680-3 (1912).

- (159) Whitmore, Popkin, Whitaker, Mattil, and Zech, *J. Am. Chem. Soc.*, 60, 2458-62 (1938).
- (160) Marvel, Mazingo, and Kirkpatrick, *J. Am. Chem. Soc.*, 61, 2003-8 (1939).
- (161) Richard and Mirjollet, *Compt. rend.*, 224, 284-6 (1947); *Chem. Abstr.*, 41, 3754 (1947).
- (162) Clarke, *J. Am. Chem. Soc.*, 30, 1144-52 (1908).
- (163) Clarke and Beggs, *J. Am. Chem. Soc.*, 34, 54-60 (1912).
- (164) Clarke and Beggs, *J. Am. Chem. Soc.*, 34, 60-2 (1912).
- (165) Hickinbottom and Schlüchterer, *Nature*, 155, 19 (1945).
- (166) Henry, *Rec. trav. chim.*, 26, 106-15 (1907).
- (167) Tolstopjatow, *J. Russ. Phys.-Chem. Soc.*, 62, 1813-28 (1930); *Chem. Zentr.*, 1931, I, 2738.
- (168) Whitmore and Lewis, *J. Am. Chem. Soc.*, 64, 2964-6 (1942).
- (169) Clarke and Jones, *J. Am. Chem. Soc.*, 34, 170-4 (1912).
- (170) Whitmore and Laughlin, *J. Am. Chem. Soc.*, 54, 4011-4 (1932).
- (171) Leroide, *Ann. chim.*, [9], 16, 354-410 (1921).
- (172) Ramart-Lucas, *Compt. rend.*, 154, 708-10 (1912); *Chem. Abstr.*, 6, 1603 (1912).
- (173) Ruggli and Businger, *Helv. Chim. Acta*, 24, 1112-26 (1941).
- (174) Lemaire, *Rec. trav. chim.*, 29, 22-84 (1910).
- (175) Lespieau and Wakeman, *Bull. soc. chim.*, [4], 51, 384-400 (1932).
- (176) Jacquemaine, *Compt. rend.*, 199, 1315-7 (1934).
- (177) Franke and Kohn, *Ber.*, 37, 4730-1 (1904).
- (178) Franke and Kohn, *Monatsh.*, 28, 997-1015 (1907).
- (179) Tiffeneau and Lévy, *Bull. soc. chim.*, [4], 33, 735-59 (1923).
- (180) Hurd and Webb, *J. Am. Chem. Soc.*, 49, 546-59 (1927).
- (181) Domratschewa, *J. Russ. Phys.-Chem. Soc.*, 46, 864-7 (1914); *Chem. Zentr.*, 1915, I, 878.
- (182) Heilbron, Jones, and Richardson, *J. Chem. Soc.*, 1949, 287-93.
- (183) Grignard and Dubien, *Ann. chim.*, [10], 2, 298-318 (1924).
- (184) Esafov and Molchanova, *J. Gen. Chem. (U.S.S.R.)*, 16, 1885-90 (1946); *Chem. Abstr.*, 41, 6185 (1947).
- (185) Colonge, *Bull. soc. chim.*, [5], 3, 413-8 (1936).
- (186) Smith, Chase, and Rhodes, *J. Am. Chem. Soc.*, 66, 1547-9 (1944).
- (187) Grignard, *Compt. rend.*, 135, 627-30 (1902); *Chem. Zentr.*, 1902, II, 1359.
- (188) Frank, Arvan, Richter, and Vanneman, *J. Am. Chem. Soc.*, 66, 4-6 (1944).
- (189) LaForge and Barthel, *J. Org. Chem.*, 10, 222-7 (1945).
- (190) Huston and Guile, *J. Am. Chem. Soc.*, 61, 69-71 (1939).
- (191) Whitmore and Williams, *J. Am. Chem. Soc.*, 55, 406-11 (1933).
- (192) Whitmore and Lewis, *J. Am. Chem. Soc.*, 64, 1619-21 (1942).
- (193) Stas, *Bull. soc. chim. Belg.*, 34, 188-90 (1925).
- (194) Blatt and Stone, *J. Am. Chem. Soc.*, 54, 1495-9 (1932).
- (195) Murat and Amouroux, *J. Pharm. Chim.*, [7], 5, 473-8 (1912); *Chem. Zentr.*, 1912, II, 103.
- (196) Whitmore and George, *J. Am. Chem. Soc.*, 64, 1239-42 (1942).
- (197) Young and Roberts, *J. Am. Chem. Soc.*, 67, 319-21 (1945).
- (198) Béhal and Sommelet, *Compt. rend.*, 138, 89-92 (1904); *Chem. Zentr.*, 1904, I, 504.
- (199) Tuot and Guyard, *Bull. soc. chim.*, [5], 14, 1087-96 (1947).
- (200) Ivanoff and Spassoff, *Bull. soc. chim.*, [4], 49, 377-9 (1931).
- (201) Young and Roberts, *J. Am. Chem. Soc.*, 66, 1444-5 (1944).
- (202) de Coster, *Bull. acad. roy. Belg.*, [5], 11, 661-5 (1925); *Chem. Zentr.*, 1926, I, 3146.

- (203) Madelung and Oberwegner, *Ber.*, 65B, 931-41 (1932).
(204) Gilman and Kirby, *J. Am. Chem. Soc.*, 54, 345-55 (1932).
(205) Fieser and Seligman, *J. Am. Chem. Soc.*, 61, 136-42 (1939).
(206) Klages, *Ber.*, 35, 2633-41 (1902).
(207) Orékhoff and Tiffeneau, *Bull. soc. chim.*, [4], 41, 839-43 (1927).
(208) Chang and Tseng, *Trans. Science Soc. China*, 7, 225-32 (1932); *Chem. Abstr.*, 26, 5555 (1932).
(209) Simons and Ramler, *J. Am. Chem. Soc.*, 65, 389-92 (1943).
(210) Marvel, Allen, and Overberger, *J. Am. Chem. Soc.*, 68, 1088-91 (1946).
(211) Pochinok, *J. Gen. Chem. (U.S.S.R.)*, 16, 1306-10 (1946); *Chem. Abstr.*, 41, 3066 (1947).
(212) Sudzuki, *J. Chem. Soc., Japan*, 63, 124-7 (1942); *Chem. Abstr.*, 41, 3046 (1947).
(213) Tiffeneau, *Ann. chim.*, [8], 10, 322-78 (1907).
(214) Salkind and Rosenfeld, *Ber.*, 57B, 1690-2 (1924).
(215) Nesmeyanov and Sazanova, *Bull. acad. sci. U.S.S.R., Classe sci. chim.*, 1941, 499-519; *Chem. Abstr.*, 37, 2723 (1943).
(216) Gilman and McGlumphy, *Bull. soc. chim.*, [4], 43, 1322-8 (1928).
(217) Crawford, Saeger, and Warneke, *J. Am. Chem. Soc.*, 64, 2862-4 (1942).
(218) Proost and Wibaut, *Rec. trav. chim.*, 59, 971-7 (1940).
(219) Sabatier and Murat, *Compt. rend.*, 154, 1771-3 (1912); *Chem. Abstr.*, 6, 2738 (1912).
(220) Hell, *Ber.*, 37, 453-8 (1904).
(221) Fuson, Armstrong, Wallace, and Kneisley, *J. Am. Chem. Soc.*, 66, 681-4 (1944).
(222) Petrov and Chel'tsova, *J. Gen. Chem. (U.S.S.R.)*, 12, 87-94 (1942); *Chem. Abstr.*, 37, 1993 (1943).
(223) Ziegler and Sauermilch, *Ber.*, 63B, 1851-64 (1930).
(224) Chelintsev and Till, *Uchenye Zapiski Saratov Gosudarst. Univ. N.G. Chernyshevskogo, Khim.*, 15, No. 4, 24-31 (1940); *Chem. Abstr.*, 35, 6953 (1941).
(225) Stoermer, *Ber.*, 39, 2288-306 (1906).
(226) Miescher and Marxer, U. S. Patent 2,411,664, Nov. 26, 1946; *Chem. Abstr.*, 41, P6276 (1947).
(227) Stoermer and Simon, *Ber.*, 37, 4163-8 (1904).
(228) Fuson, McKusick, and Mills, *J. Org. Chem.*, 11, 60-6 (1946).
(229) Vavon, Rivière, and Angelo, *Compt. rend.*, 222, 959-61 (1946); *Chem. Abstr.*, 40, 4365 (1946).
(230) Vavon and Angelo, *Compt. rend.*, 224, 1435-7 (1947); *Chem. Abstr.*, 41, 6221 (1947).
(231) Whitmore, Schiessler, Rowland, and Cosby, *J. Am. Chem. Soc.*, 69, 235-7 (1947).
(232) Jacquemain, *Compt. rend.*, 198, 482-4 (1934); *Chem. Abstr.*, 28, 2328 (1934).
(233) Arens, van Dorp, van Dijk, Brandt, Hubers, and Pieters, *Rec. trav. chim.*, 67, 973-9 (1948).
(234) Ramart-Lucas, *Ann. chim.*, [8], 30, 349-432 (1913).
(235) Oparin, *J. Russ. Phys.-Chem. Soc.*, 61, 2011-5 (1929); *Chem. Zentr.*, 1930,1, 3556; *Chem. Abstr.*, 24, 4785 (1930).
(236) Kanao and Shinozuka, *J. Pharm. Soc. Japan*, 50, 148-52 (1930); *Chem. Zentr.*, 1931,1, 1743.
(237) Sackur, *Compt. rend.*, 208, 1092-4 (1939); *Chem. Abstr.*, 33, 9296 (1939).
(238) McKenzie, Mills, and Myles, *Ber.*, 63B, 904-11 (1930).

- (239) Esafov, Gulyakov, Kargapol'tseva, Kulekova, Razmyslov, and Toporov, *J. Gen. Chem.* (U.S.S.R.), 10, 1973-7 (1940); *Chem. Abstr.*, 35, 3958 (1941).
- (240) Bruylants, *Bull. soc. chim. Belg.*, 36, 519-32 (1927).
- (241) Harries and Weil, *Ber.*, 37, 845-50 (1904).
- (242) Escourru, *Bull. soc. chim.*, [4], 39, 1121-38 (1926).
- (243) Barbier, *Compt. rend.*, 128, 110-1 (1899); *J. Chem. Soc.*, 76, 1, 323 (1899).
- (244) Sand and Singer, *Ber.*, 35, 3170-87 (1902).
- (245) Nazarov and Terekhova, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1943, 286-95; *Chem. Abstr.*, 38, 5489 (1944).
- (246) Speck and Bost, *J. Org. Chem.*, 11, 788-94 (1946).
- (247) Slavianov, *J. Russ. Phys.-Chem. Soc.*, 39, 140-60 (1907); *Chem. Abstr.*, 1, 2077 (1907).
- (248) Gredy, *Bull. soc. chim.*, [5], 2, 1038-44 (1935).
- (249) Calingaert and Soroos, *J. Am. Chem. Soc.*, 58, 635-6 (1936).
- (250) Brokaw and Brode, *J. Org. Chem.*, 13, 194-9 (1948).
- (251) Wilson, Roberts, and Young, *J. Am. Chem. Soc.*, 72, 218-9 (1950).
- (252) Tiffeneau and Lévy, *Bull. soc. chim.*, [4], 33, 759-79 (1923).
- (253) Spaeth, Geissman, and Jacobs, *J. Org. Chem.*, 11, 399-404 (1946).
- (254) Buu-Hoï and Nguyen-Hoán, *Rec. trav. chim.*, 68, 5-33 (1949).
- (255) Young and Roberts, *J. Am. Chem. Soc.*, 68, 649-52 (1946).
- (256) Kohler, *Am. Chem. J.*, 42, 375-401 (1909).
- (257) Tarbell and Sato, *J. Am. Chem. Soc.*, 68, 1094-6 (1946).
- (258) Temnikova, *Vestnik Leningrad Univ.*, 1947, 138-45; *Chem. Abstr.*, 42, 4155 (1948).
- (259) Levy and Cope, *J. Am. Chem. Soc.*, 66, 1684-8 (1944).
- (260) Sabatier and Murat, *Compt. rend.*, 156, 1430-4 (1913); *Chem. Abstr.*, 7, 3109 (1913).
- (261) Gilman and Harris, *J. Am. Chem. Soc.*, 54, 2072-5 (1932).
- (262) Mills and Grigor, *J. Chem. Soc.*, 1934, 1568-70.
- (263) Tiffeneau, Lévy, and Dietz, *Bull. soc. chim.*, [5], 2, 1848-55 (1935).
- (264) Tiffeneau, Orékhoff, and Roger, *Bull. soc. chim.*, [4], 49, 1757-65 (1931).
- (265) Meyer, *Helv. Chim. Acta*, 18, 101-3 (1935).
- (266) Barbier and Locquin, *Bull. soc. chim.*, [4], 9, 717-22 (1911).
- (267) Werner and Bogert, *J. Org. Chem.*, 3, 578-87 (1939).
- (268) Houben, *Ber.*, 35, 3587-92 (1902).
- (269) Cason and Prout, *J. Am. Chem. Soc.*, 66, 46-50 (1944).
- (270) Mannich and Hof, *Arch. Pharm.*, 265, 589-98 (1927); *Chem. Zentr.*, 1928, 1, 201.
- (271) Mironescu, Ioanid, and Nicolescu, *Bul. soc. chim. România*, 14, 187 (1932); *Chem. Abstr.*, 27, 4231 (1933).
- (272) Minnis, *J. Am. Chem. Soc.*, 51, 2143-7 (1929).
- (273) Shriner and Sharp, *J. Org. Chem.*, 4, 575-82 (1939).
- (274) Buchta and Haagner, *Ber.*, 81B, 251-3 (1948); *Chem. Abstr.*, 43, 1039 (1949).
- (275) Kohler and Johnstin, *Am. Chem. J.*, 33, 35-45 (1905).
- (276) Koelsch, *J. Am. Chem. Soc.*, 65, 1640-3 (1943).
- (277) Ponomarev, *Uchenye Zapiski Saratov Gosudarst. Univ., Sbornik Nauch., Rabot Studentov*, 1938, 20-4; *Khim. Referat. Zhur.*, 1939, No. 9, 31; *Chem. Abstr.*, 34, 5830 (1940).
- (278) Kohler and Burnley, *Am. Chem. J.*, 43, 412-8 (1910).
- (279) Lipp, Buchkremer, and Seeles, *Ann.*, 499, 1-25 (1932).
- (280) Burmistrov and Shilov, *J. Gen. Chem.* (U.S.S.R.), 16, 295-9 (1946); *Chem. Abstr.*, 41, 474 (1947).

- (281) Lauer and Renfrew, *J. Am. Chem. Soc.*, 67, 808-10 (1945).
(282) Orechoff and Meerson, *Ber.*, 45, 1926-30 (1912).
(283) Mazurewitsch, *J. Russ. Phys.-Chem. Soc.*, 43, 973-90 (1911); *Chem. Zentr.*, 1911,11, 1921.
(284) Grischkewitsch-Trochimowski, *J. Russ. Phys.-Chem. Soc.*, 41, 1326-32 (1909); *Chem. Zentr.*, 1910,1, 739.
(285) Yéramian, *Compt. rend.*, 173, 362-4 (1921).
(286) Klages, *Ber.*, 37, 1721-6 (1904).
(287) Blicke and Powers, *J. Am. Chem. Soc.*, 51, 3378-83 (1929).
(288) Schwartzkopf and Bush, British Patent 584,705, Jan. 21, 1947; *Chem. Abstr.*, 41, P4515 (1947).
(289) Temnikova, *J. Gen. Chem. (U.S.S.R.)*, 11, 77-91 (1941); *Chem. Abstr.*, 35, 6580 (1941).
(290) Venus-Danilova and Brichko, *J. Gen. Chem. (U.S.S.R.)*, 17, 1549-58 (1947); *Chem. Abstr.*, 42, 2243 (1948).
(291) Weill, *Bull. soc. chim.*, [4], 49, 1795-1806 (1931).
(292) Temnikova, *J. Gen. Chem. (U.S.S.R.)*, 15, 514-23 (1945); *Chem. Abstr.*, 40, 4695 (1946).
(293) Skita, Keil, and Baesler, *Ber.*, 66B, 858-66 (1933).
(294) Esafov, Vladimirtsev, Kassiklina, and Raïkher, *J. Gen. Chem. (U.S.S.R.)*, 13, 818-22 (1943); *Chem. Abstr.*, 39, 904 (1945).
(295) Temnikova and Veksler, *J. Gen. Chem. (U.S.S.R.)*, 11, 3-8 (1941); *Chem. Abstr.*, 35, 5459 (1941).
(296) Montagne and Rousseau, *Compt. rend.*, 196, 1165-7 (1933).
(297) Karrer, Shibata, Wettstein, and Jacobowicz, *Helv. Chem. Acta*, 13, 1292-308 (1930).
(298) Petrov and Vittikh, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1944, 152-5; *Chem. Abstr.*, 39, 1618 (1945).
(299) Whitmore and Laughlin, *J. Am. Chem. Soc.*, 56, 1128-30 (1934).
(300) Brachin, *Bull. soc. chim.*, [3], 35, 1163-79 (1906).
(301) Buu-Hoï and Hiong-Ki-Wei, *Compt. rend.*, 220, 175-7 (1945); *Chem. Abstr.*, 40, 2828 (1946).
(302) Padbury and Lindwall, *J. Am. Chem. Soc.*, 67, 1268-70 (1945).
(303) Strating and Backer, *Rec. trav. chim.*, 62, 57-67 (1943); *Chem. Abstr.*, 39, 2497 (1945).
(304) Kondo and Osawa, *J. Pharm. Soc. Japan*, 56, 73-4 (1936); *Chem. Abstr.*, 32, 5837 (1938).
(305) Whitmore, Whitaker, Mosher, Breivik, Wheeler, Miner, Sutherland, Wagner, Clapper, Lewis, Lux, and Popkin, *J. Am. Chem. Soc.*, 63, 643-54 (1941).
(306) Kondo and Kokeguchi, *J. Pharm. Soc. Japan*, 57, 573-9 (1937); *Chem. Abstr.*, 31, 6230 (1937).
(307) Lüttringhaus, Wagner-von Sääf, Sucker, and Borth, *Ann.*, 557, 26-45 (1945); *Chem. Abstr.*, 40, 5418 (1946).
(308) Maxim and Georgescu, *Bull. soc. chim.*, [5], 3, 1114-24 (1936).
(309) Young and Roberts, *J. Am. Chem. Soc.*, 68, 1472-5 (1946).
(310) Willemart, *Bull. soc. chim.*, [5], 2, 867-82 (1935).
(311) Venus-Danilova and Brichko, *J. Gen. Chem. (U.S.S.R.)*, 17, 1849-57 (1947); *Chem. Abstr.*, 42, 4160 (1948).
(312) Fuson, Armstrong, and Shenk, *J. Am. Chem. Soc.*, 66, 964-7 (1944).
(313) Temnikova, *J. Gen. Chem. (U.S.S.R.)*, 8, 1022-8 (1939); *Chem. Abstr.*, 33, 3777 (1939).
(314) Kloetzel, *J. Am. Chem. Soc.*, 62, 3405-10 (1940).
(315) Adams and Gross, *J. Am. Chem. Soc.*, 64, 1786-90 (1942).

- (316) Young and Roberts, *J. Am. Chem. Soc.*, 66, 2131 (1944).
(317) Dev, *Current Sci.*, 16, 377-8 (1947); *Chem. Abstr.*, 42, 5890 (1948).
(318) Chichibabin and Stepanov, *Ber.*, 62B, 1068-75 (1929).
(319) Mironescu and Ioanid, *Bul. soc. chim. România*, 17, 107-29 (1935); *Chem. Abstr.*, 30, 1053 (1936).
(320) Lucas, *Compt. rend.*, 150, 1058-61 (1910); *Chem. Zentr.*, 1910,11, 77.
(321) Lucas, *Compt. rend.*, 152, 1771-4 (1911); *Chem. Zentr.*, 1911,11, 360.
(322) Weill, *Bull. soc. chim.*, [4], 49, 1811-23 (1931).
(323) Petrov and Karlik, *J. Gen. Chem. (U.S.S.R.)*, 11, 1100-3 (1941); *Chem. Abstr.*, 37, 4049 (1942).
(324) Whitmore and Lester, *J. Am. Chem. Soc.*, 64, 1247-51 (1942).
(325) Tschitschibabin, *J. prakt. Chem.*, [2], 75, 526-8 (1905); *Chem. Abstr.*, 1, 2478 (1907).
(326) Tschitschibabin, *J. Russ. Phys.-Chem. Soc.*, 7, 1056-7 (1906); *Chem. Abstr.*, 1, 1414 (1907).
(327) Fuson, McKusick, and Spangler, *J. Am. Chem. Soc.*, 67, 597-601 (1945).
(328) Bergmann and Weizmann, *J. Org. Chem.*, 9, 352-8 (1944).
(329) Bauer, *Ber.*, 38, 688-90 (1905).
(330) Haworth, Letsky, and Mavin, *J. Chem. Soc.*, 1932, 1784-92.
(331) Fieser and Newman, *J. Am. Chem. Soc.*, 58, 2376-82 (1936).
(332) Tarbell and Weaver, *J. Am. Chem. Soc.*, 62, 2747-50 (1940).
(333) Adams, Chen, and Loewe, *J. Am. Chem. Soc.*, 67, 1534-7 (1945).
(334) Bergmann and Weizmann, *J. Org. Chem.*, 11, 592-9 (1946).
(335) Tsatsas, *Ann. chim.*, [12], 1, 342-94 (1946).
(336) Tsatsas, *Compt. rend.*, 220, 889-91 (1945); *Chem. Abstr.*, 40, 3739 (1946).
(337) Rajagopalan, *J. Indian Chem. Soc.*, 17, 576-82 (1940).
(338) Walther, *J. pharm. chim.*, 27, 467-9 (1938); *Chem. Abstr.*, 32, 6237 (1938).
(339) Lipp and Quaedvlieg, *Ber.*, 62B, 2311-22 (1929).
(340) Morton and Peakes, *J. Am. Chem. Soc.*, 55, 2110-2 (1933).
(341) Forrest, *J. Chem. Soc.*, 1946, 333-9.
(342) Fuson and Armstrong, *J. Am. Chem. Soc.*, 63, 2650-2 (1941).
(343) Marvel, Dietz, and Himel, *J. Org. Chem.*, 7, 392-6 (1942).
(344) Loury, *Compt. rend.*, 194, 1747-9 (1932).
(345) Koelsch, *J. Am. Chem. Soc.*, 54, 2487-93 (1932).
(346) Maxim and Angelesco, *Bull. soc. chim.*, [4], 51, 1365-70 (1932).
(347) Maxim and Angelesco, *Bull. soc. chim.*, [5], 1, 1128-33 (1934).
(348) Grummit, Buck, and Becker, *J. Am. Chem. Soc.*, 67, 2265-6 (1945).
(349) Bergmann and Bondi, *Ber.*, 64B, 1455-80 (1931).
(350) Klages, *Ber.*, 35, 2646-9 (1902).
(351) Kharasch and Weinhouse, *J. Org. Chem.*, 1, 209-30 (1936).
(352) Tarassow, *J. Russ. Phys.-Chem. Soc.*, 41, 1309-13 (1910); *Chem. Zentr.*, 1910,1, 739.
(353) Klages and Heilmann, *Ber.*, 37, 1447-57 (1904).
(354) LaGrave, *Ann. chim.*, [10], 8, 363-446 (1927).
(355) Kharasch, Kleiger, Martin, and Mayo, *J. Am. Chem. Soc.*, 63, 2305-7 (1941).
(356) Noller, Grebe, and Knox, *J. Am. Chem. Soc.*, 54, 4690-6 (1932).
(357) Davies, Dixon, and Jones, *J. Chem. Soc.*, 1930, 1916-21.
(358) Grignard and Courtot, *Compt. rend.*, 158, 1763-6 (1914); *Chem. Abstr.*, 8, 3436 (1914).
(359) Mihailescu and Caragea, *Bull. sect. sci. acad. romaine*, 12, No. 4/5, 7-18 (1929); *Chem. Abstr.*, 24, 2116 (1930).
(360) Acree, *Ber.*, 37, 2753-64 (1904).
(361) Tadros, *Nature*, 148, 53 (1941).

- (362) Banus and Vila, *Anales soc. españ. fis. quim.*, 19, 326-46 (1921); *Chem. Zentr.*, 1924,1, 1525.
- (363) Blicke and Weinkauff, *J. Am. Chem. Soc.*, 54, 1446-53 (1932).
- (364) Acree, *Ber.*, 37, 990-4 (1904).
- (365) Kovache, *Ann. chim.*, [9], 10, 184-248 (1918).
- (366) Marxer, *Helv. Chim. Acta*, 24, 209-15E (1941).
- (367) Hess and Weltzien, *Ber.*, 54B, 2511-21 (1921).
- (368) Acree, *Ber.*, 37, 625-8 (1904).
- (369) Meyer and Schuster, *Ber.*, 55B, 815-9 (1922).
- (370) Straus and Ehrenstein, *Ann.*, 442, 93-118 (1925).
- (371) Ehrlich and Sachs, *Ber.*, 36, 4296-9 (1903).
- (372) Sweet and Marvel, *J. Am. Chem. Soc.*, 54, 1184-90 (1932).
- (373) Bowden, Harris, and Roberts, *J. Chem. Soc.*, 1939, 302-7.
- (374) Bowden and Harris, *J. Chem. Soc.*, 1939, 307-10.
- (375) Schlenk and Weickel, *Ann.*, 368, 295-304 (1909).
- (376) Grignard and Courtot, *Compt. rend.*, 152, 1493-5 (1911); *Chem. Abstr.*, 5, 3409 (1911).
- (377) Bachmann, *J. Am. Chem. Soc.*, 56, 1363-7 (1934).
- (378) Ziegler, *Ann.*, 434, 34-78 (1923).
- (379) Koelsch, *J. Am. Chem. Soc.*, 54, 3384-9 (1932).
- (380) Tschelinzew, Tronow, and Terentjew, *J. Russ. Phys.-Chem. Soc.*, 47, 1211-23 (1915); *Chem. Zentr.*, 1916,1, 1247.
- (381) Bachmann and Hertzner, *Organic Syntheses*, 23, 98-100 (1943).
- (382) Marvel, Kaplan, and Himel, *J. Am. Chem. Soc.*, 63, 1892-6 (1941).
- (383) Nesmeyanov and Pecherskaya, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1943, 317-8; *Chem. Abstr.*, 38, 5492 (1944).
- (384) Ivanoff and Pchenitchny, *Bull. soc. chim.*, [5], 1, 223-33 (1934).
- (385) Courtot and Tchelitcheff, *Compt. rend.*, 217, 201-3 (1943); *Chem. Abstr.*, 38, 5502 (1944).
- (386) Bachmann and Kloetzel, *J. Org. Chem.*, 3, 55-61 (1938).
- (387) Tadros, Farahat, and Robson, *J. Chem. Soc.*, 1949, 439-41.
- (388) Petrov and Kaplan, *Izvest. Akad. Nauk. S.S.S.R., Otdel Khim. Nauk.*, 1947, 295-308; *Chem. Abstr.*, 43, 1718 (1949).
- (389) Pfeiffer and Blank, *J. prakt. Chem.*, [2], 153, 242-56 (1939).
- (390) Soc. pour l'ind. chim. à Bâle, Swiss Patents 235,496, Apr. 3, 1945, 235,497, Apr. 16, 1945; *Chem. Abstr.*, 43, P7056 (1949).
- (391) Simpson and Stephenson, *J. Chem. Soc.*, 1942, 353-8.
- (392) Baeyer, *Ann.*, 372, 80-151 (1910).
- (393) Fuson and Meek, *J. Org. Chem.*, 10, 551-61 (1945).
- (394) Baeyer, *Ann.*, 354, 152-204 (1907).
- (395) Kauffmann and Pannwitz, *Ber.*, 45, 766-76 (1912).
- (396) Porter and Hirst, *J. Am. Chem. Soc.*, 41, 1264-7 (1919).
- (397) Stoermer and Fincke, *Ber.*, 42, 3115-34 (1909).
- (398) Simpson, *J. Chem. Soc.*, 1946, 673-5.
- (399) Dzięwoński and Marusińska, *Bull. intern. polon. sci., Classe sci. math. nat.*, 1938A, 316-23; *Chem. Abstr.*, 33, 1712 (1939).
- (400) Grateau, *Compt. rend.*, 196, 1619-21 (1933).
- (401) Kohler and Blanchard, *J. Am. Chem. Soc.*, 57, 367-71 (1935).
- (402) Campbell and Soffer, *J. Am. Chem. Soc.*, 64, 417-25 (1943).
- (403) Conant and Schultz, *J. Am. Chem. Soc.*, 55, 2098-104 (1933).
- (404) Földi and Demjén, *Ber.*, 74B, 930-4 (1941).
- (405) Giacalone, *Gazz. chim. ital.*, 67, 464-8 (1937); *Chem. Abstr.*, 32, 1689 (1938).

- (406) Neunhoeffter, *Ann.*, 509, 115-30 (1934).
- (407) Schneider and Spielmann, *J. Biol. Chem.*, 142, 345-54 (1942).
- (408) Clark and Linnell, *J. Pharm. Pharmacol.*, 1, 211-8 (1949); *Chem. Abstr.*, 43, 8367 (1949).
- (409) Smith and Sprung, *J. Am. Chem. Soc.*, 65, 1276-83 (1943).
- (410) Preobrazhenskii and Shokina, *J. Gen. Chem. (U.S.S.R.)*, 15, 65-9 (1945); *Chem. Abstr.*, 40, 1793 (1946).
- (411) Smith and Sprung, U. S. Patent 2,241,090, May 27, 1947; *Chem. Abstr.*, 41, P5543 (1947).
- (412) Kleinfeller and Eckert, *Ber.*, 62B, 1598-600 (1929).
- (413) Chu and Chu, *J. Chinese Chem. Soc.*, 9, 190-5 (1942).
- (414) Roger and McGregor, *J. Chem. Soc.*, 1934, 442-4.
- (415) Bachmann and Ferguson, *J. Am. Chem. Soc.*, 56, 2081-4 (1934).
- (416) Osterseizer, *Monatsh.*, 34, 795-6 (1913).
- (417) Chamberlain and Dull, *J. Am. Chem. Soc.*, 50, 3088-92 (1928).
- (418) Carpenter and Turner, *J. Chem. Soc.*, 1934, 869-72.
- (419) Kusjimin, *J. Russ. Phys.-Chem. Soc.*, 41, 1314-9 (1909); *Chem. Zentr.*, 1910,I, 739.
- (420) Wright, *J. Am. Chem. Soc.*, 61, 1152-6 (1939).
- (421) Bradsher and Wissow, *J. Am. Chem. Soc.*, 68, 1094-6 (1946).
- (422) McKenzie and Mills, *Ber.*, 62B, 1784-94 (1929).
- (423) Zugrăvescu and Zugrăvescu, *Bul. soc. chim. România*, 20A, 225-30 (1938); *Chem. Abstr.*, 34, 1974 (1940).
- (424) Fuson and Robertson, *J. Org. Chem.*, 7, 466-71 (1942).
- (425) Staudinger, *Ann.*, 356, 51-123 (1907).
- (426) Roger and McGregor, *J. Chem. Soc.*, 1934, 1850-3.
- (427) Reeves and Lindwall, *J. Am. Chem. Soc.*, 64, 1086-9 (1942).
- (428) McKenzie and Wren, *J. Chem. Soc.*, 97, 473-86 (1910).
- (429) Tiffeneau and Dorlencourt, *Compt. rend.*, 143, 126-8 (1906); *Chem. Zentr.*, 1906,II, 670.
- (430) Kohler, Richtmyer, and Hester, *J. Am. Chem. Soc.*, 53, 205-21 (1931).
- (431) Bachmann and Moser, *J. Am. Chem. Soc.*, 54, 1124-33 (1932).
- (432) Lévy and Pernot, *Bull. soc. chim.*, [4], 49, 1730-8 (1931).
- (433) Acree, *Am. Chem. J.*, 33, 180-95 (1905).
- (434) Roger and McKay, *J. Chem. Soc.*, 1931, 2229-38.
- (435) Bergmann, Winter, and Schreiber, *Ann.*, 500, 122-36 (1933).
- (436) Mitter and De, *J. Indian Chem. Soc.*, 16, 199-208 (1939).
- (437) Kohler and Tishler, *J. Am. Chem. Soc.*, 54, 1594-600 (1932).
- (438) Löwenbein, Pongrácz, and Spiess, *Ber.*, 57B, 1517-26 (1924).
- (439) Johlin, *J. Am. Chem. Soc.*, 39, 291-3 (1917).
- (440) Neunhoeffter and Nerdel, *Ann.*, 526, 47-58 (1936).
- (441) Buu-Hoi, *Bull. soc. chim.*, [5], 13, 117-23 (1946).
- (442) Ivanoff and Spassoff, *Bull. soc. chim.*, [4], 49, 371-5 (1931).
- (443) Orékhoff, *Bull. soc. chim.*, [4], 25, 108-11 (1919).
- (444) McKenzie and Richardson, *J. Chem. Soc.*, 123, 79-91 (1923).
- (445) Gilman and Heckert, *J. Am. Chem. Soc.*, 42, 1010-4 (1920).
- (446) Smith and Hoehn, *J. Am. Chem. Soc.*, 63, 1176-8 (1941).
- (447) Gverdseteli, *J. Gen. Chem. (U.S.S.R.)*, 18, 1187-8 (1948); *Chem. Abstr.*, 43, 1754 (1949).
- (448) Colonge and Pichat, *Compt. rend.*, 226, 673-5 (1948); *Chem. Abstr.*, 42, 4993 (1948).
- (449) Albescio, *Ann. chim.*, [9], 18, 216-62 (1922).
- (450) Kohler and Erickson, *J. Am. Chem. Soc.*, 53, 2301-9 (1931).

- (451) Fuson, Kaiser, and Speck, *J. Org. Chem.*, 6, 845-51 (1941).
(452) Taylor and Connor, *J. Org. Chem.*, 6, 696-704 (1941).
(453) Bergmann and Hampson, *J. Chem. Soc.*, 1935, 989-93.
(454) Newman and Smith, *J. Org. Chem.*, 13, 592-8 (1948).
(455) Vorländer and Siebert, *Ber.*, 39, 1024-35 (1906).
(456) Vorländer, Osterburg, and Meye, *Ber.*, 56B, 1136-44 (1923).
(457) Smedley, *J. Chem. Soc.*, 97, 1484-94 (1910).
(458) Koelsch and Prill, *J. Am. Chem. Soc.*, 67, 1296-9 (1945).
(459) Guyot and Catel, *Compt. rend.*, 140, 254-6 (1905); *Chem. Zentr.*, 1905, I, 679.
(460) Haworth, Mavin, and Sheldrick, *J. Chem. Soc.*, 1934, 454-61.
(461) Buu-Hoï, Hiong-Ki-Wei, Lacassagne, and Lecocq, *Compt. rend.*, 219, 589-91 (1944); *Chem. Abstr.*, 40, 1489 (1946).
(462) Burger and Deiner, *J. Am. Chem. Soc.*, 67, 566-9 (1945).
(463) McKenzie, Martin, and Rule, *J. Chem. Soc.*, 105, 1583-91 (1914).
(464) Ramart and Albesco, *Compt. rend.*, 174, 1289-91 (1922); *Chem. Zentr.*, 1922, III, 1290.
(465) Gilman and Kirby, *J. Am. Chem. Soc.*, 63, 2046-8 (1941).
(466) Kohler and Barnes, *J. Am. Chem. Soc.*, 56, 211-4 (1934).
(467) Blicke, Smith, and Powers, *J. Am. Chem. Soc.*, 54, 1465-71 (1932).
(468) Campbell, Anderson, and Gilmore, *J. Chem. Soc.*, 1940, 819-21.
(469) Austin and Johnson, *J. Am. Chem. Soc.*, 54, 647-60 (1932).
(470) Bradsher and Amore, *J. Am. Chem. Soc.*, 63, 493-5 (1941).
(471) Bradsher and Rosher, *J. Am. Chem. Soc.*, 61, 1524-5 (1939).
(472) Kauffmann and Fritz, *Ber.*, 41, 4423-7 (1908).
(473) Kauffmann and Grombach, *Ber.*, 38, 794-801 (1905).
(474) Kauffmann and Kieser, *Ber.*, 46, 3788-801 (1913).
(475) Sachs and Thonet, *Ber.*, 37, 3327-34 (1904).
(476) Ziegler and Ochs, *Ber.*, 55B, 2257-77 (1922).
(477) Busignies, *Compt. rend.*, 149, 348-50 (1909); *Chem. Zentr.*, 1909, II, 1450.
(478) Mills, *J. Chem. Soc.*, 1934, 1565-8.
(479) Clemo, Kefford, and Osborne, *J. Chem. Soc.*, 1939, 360-1.
(480) Bergmann, *J. Org. Chem.*, 4, 1-13 (1939).
(481) Shelton and Van Campen, U. S. Patent 2,430,891, Nov. 18, 1947; *Chem. Abstr.*, 42, P1968 (1948).
(482) Robinson and Slater, *J. Chem. Soc.*, 1941, 376-85.
(483) Sah, *J. Chinese Chem. Soc.*, 13, 89-95 (1946); *Chem. Abstr.*, 41, 5869 (1947).
(484) Cromwell, *J. Am. Chem. Soc.*, 69, 258-60 (1947).
(485) Buu-Hoï, Nguyen-Hoàn, Lecocq, and de Clercq, *Rec. trav. chim.*, 67, 795-812 (1948).
(486) Pérard, *Ann. chim.*, [9], 7, 344, ftnote (1917).
(487) van Dorp and Arens, *Nature*, 160, 189 (1947).
(488) Lutz and Tyson, *J. Am. Chem. Soc.*, 56, 1341-2 (1934).
(489) Fieser and Price, *J. Am. Chem. Soc.*, 58, 1838-43 (1936).
(490) Smith and Hanson, *J. Am. Chem. Soc.*, 57, 1326-8 (1935).
(491) Fuson, Armstrong, and Speck, *J. Org. Chem.*, 7, 297-302 (1942).
(492) Bergmann and Wolff, *J. Am. Chem. Soc.*, 54, 1644-7 (1932).
(493) Haworth, *J. Chem. Soc.*, 1932, 2717-20.
(494) Bradsher and Wissow, *J. Am. Chem. Soc.*, 65, 2034-5 (1943).
(495) Weizmann and Bergmann, *J. Am. Chem. Soc.*, 60, 2647-50 (1938).
(496) Whitmore, Sutherland, and Cosby, *J. Am. Chem. Soc.*, 64, 1360-4 (1942).
(497) Hey and Carter, British Patent 586,493, March 20, 1947; *Chem. Abstr.*, 42, P1967 (1948).

- (498) Orékhoff, *Bull. soc. chim.*, [4], 25, 111-5 (1919).
- (499) Frösch, Zellner, and Zak, *Monatsh.*, 55, 25-46 (1930).
- (500) Fuson, Armstrong, Chadwick, Kneisley, Rowland, Shenk, and Soper, *J. Am. Chem. Soc.*, 67, 386-93 (1945).
- (501) Fuson, Foster, Shenk, and Maynert, *J. Am. Chem. Soc.*, 67, 1937-9 (1945).
- (502) Lutz, Allison, Ashburn, Bailey, Clarke, Codington, Deintert, Freek, Jordon, Leake, Martin, Nicodemus, Rowlett, Shearer, Smith, and Wilson, *J. Org. Chem.*, 12, 617-703 (1947).
- (503) Buu-Hoi, Nguyen-Hoàn, and Royer, *Bull. soc. chim.*, [5], 14, 84-6 (1947).
- (504) Adams, Harfenist, and Loewe, *J. Am. Chem. Soc.*, 71, 1624-8 (1949).
- (505) Ullmann and Mourawiew-Winigradoff, *Ber.*, 38, 2213-9 (1905).
- (506) Bauer and Breit, *Ber.*, 39, 1916-21 (1906).
- (507) Kohler, *Ber.*, 38, 1203-8 (1905).
- (508) Fuson, Byers, Sperati, Foster, and Warfield, *J. Org. Chem.*, 10, 69-75 (1945).
- (509) Weinstock and Fuson, *J. Am. Chem. Soc.*, 58, 1233-6 (1936).
- (510) Fuson and McKusick, *J. Am. Chem. Soc.*, 65, 60-4 (1943).
- (511) Bergmann and Israelashvili, *J. Am. Chem. Soc.*, 68, 1-5 (1946).
- (512) Dilthey and Stephen, *J. prakt. Chem.*, [2], 152, 114-25 (1939).
- (513) Stuart and Tallman, *J. Am. Chem. Soc.*, 65, 1579-81 (1943).
- (514) Winternitz and Mousseron, *Bull. soc. chim.*, [5], 15, 567-70 (1948); *Chem. Abstr.*, 42, 7279 (1948).
- (515) Fuson and Gaertner, *J. Org. Chem.*, 13, 496-501 (1948).
- (516) Tarbell and Lindstrom, *J. Am. Chem. Soc.*, 68, 1930-2 (1946).
- (517) Wizinger and Cyriax, *Helv. Chim. Acta*, 28, 1018-27 (1945).
- (518) Stuart, Shukis, and Tallman, *J. Am. Chem. Soc.*, 67, 1475-8 (1945).
- (519) Fuson and Speck, *J. Am. Chem. Soc.*, 64, 2446-8 (1942).
- (520) Wilds and Biggerstaff, *J. Am. Chem. Soc.*, 67, 789-93 (1945).
- (521) Smith, Wawzonek, and Miller, *J. Org. Chem.*, 6, 229-35 (1941).
- (522) Kauffmann, *Ann.*, 344, 30-76 (1906).
- (523) Thomas, *Compt. rend.*, 146, 642-5 (1908); *Chem. Zentr.*, 1908,1, 1784.
- (524) Wahl and Meyer, *Bull. soc. chim.*, [4], 7, 28-31 (1910).
- (525) Kohlstadt, *Helv. Chim. Acta*, 27, 685-701 (1944).
- (526) Votoček and Matějka, *Ber.*, 46, 1755-9 (1913).
- (527) Anderson and Thomas, *J. Am. Chem. Soc.*, 65, 234-8 (1943).
- (528) Fuson and Tull, *J. Am. Chem. Soc.*, 71, 2543-6 (1949).
- (529) Gilman and Jones, *J. Am. Chem. Soc.*, 62, 1243-7 (1940).
- (530) Fuson, Armstrong, Kneisley, and Shenk, *J. Am. Chem. Soc.*, 66, 1464-6 (1944).
- (531) Hudson, *J. Chem. Soc.*, 1946, 754-5.
- (532) Willstaedt, Swedish Patent 115,343, Nov. 13, 1945; *Chem. Abstr.*, 41, P158 (1947).
- (533) Newman, *J. Am. Chem. Soc.*, 60, 1368-70 (1938).
- (534) Newman and Orchin, *J. Am. Chem. Soc.*, 60, 586-9 (1938).
- (535) Newman, *J. Am. Chem. Soc.*, 59, 1003-6 (1937).
- (536) Jaeger and Robinson, *J. Chem. Soc.*, 1941, 744-7.
- (537) Julian and Gist, *J. Am. Chem. Soc.*, 57, 2030-2 (1935).
- (538) Kohler and Barnes, *J. Am. Chem. Soc.*, 55, 690-5 (1933).
- (539) Kohler and Sonnichsen, *J. Am. Chem. Soc.*, 60, 2650-2 (1938).
- (540) Linnell and Roushdi, *Quart. J. Pharm. Pharmacol.*, 14, 270-80 (1941); *Chem. Abstr.*, 36, 2544 (1942).
- (541) Clarkson and Gomberg, *J. Am. Chem. Soc.*, 52, 2881-91 (1930).
- (542) Cromwell, *J. Am. Chem. Soc.*, 69, 1857-60 (1947).
- (543) Badger, *J. Chem. Soc.*, 1941, 535-8.

- (544) Cromwell, *J. Am. Chem. Soc.*, 62, 3470-3 (1940).
(545) Chu, *J. Chinese Chem. Soc.*, 7, 14-9 (1939).
(546) Linnell and Sharma, *Quart. J. Pharm. Pharmacol.*, 14, 259-69 (1941); *Chem. Abstr.*, 36, 2546 (1942).
(547) Schoepfle and Trepp, *J. Am. Chem. Soc.*, 54, 4059-65 (1932).
(548) Newman and Wise, *J. Am. Chem. Soc.*, 63, 2109-11 (1941).
(549) Tadros, British Patent, 602,269, May 24, 1948; *Chem. Abstr.*, 42, P8214 (1948).
(550) Hudson, *J. Chem. Soc.*, 1946, 76-8.
(551) Cromwell and Burch, *J. Am. Chem. Soc.*, 66, 872-3 (1944).
(552) McKenzie and Boyle, *J. Chem. Soc.*, 119, 1131-40 (1921).
(553) Stuart, Shukis, Tallman, McCann, and Treves, *J. Am. Chem. Soc.*, 68, 728-33 (1946).
(554) Bachmann, Hoffman, and Whitehead, *J. Org. Chem.*, 8, 320-30 (1943).
(555) Barnett, Cook, and Nixon, *J. Chem. Soc.*, 1927, 504-12.
(556) Bergmann and Weiss, *Ber.*, 64B, 1485-93 (1931).
(557) Cook, Heilbron, and Lewis, *J. Chem. Soc.*, 1942, 659-61.
(558) Meyer and Streuli, *Helv. Chim. Acta*, 20, 1179-83 (1937).
(559) Kohler and Bruce, *J. Am. Chem. Soc.*, 53, 1994-8 (1931).
(560) Miescher and Anner, U. S. Patent 2,459,949, Jan. 5, 1949; *Chem. Abstr.*, 43, P3849 (1949).
(561) Cromwell and Cram, *J. Am. Chem. Soc.*, 71, 2579-80 (1949).
(562) Bachmann, *J. Am. Chem. Soc.*, 57, 555-9 (1935).
(563) Tschitschibabin, *J. prakt. Chem.*, [2], 84, 760-77 (1911).
(564) Tschitschibabin, *Ber.*, 46, 2554-6 (1913).
(565) Julian, Cole, and Wood, *J. Am. Chem. Soc.*, 57, 2508-13 (1935).
(566) Kohler and Weiner, *J. Am. Chem. Soc.*, 56, 434-8 (1934).
(567) Kohler and Tishler, *J. Am. Chem. Soc.*, 57, 217-24 (1935).
(568) McKenzie and Winton, *J. Chem. Soc.*, 1940, 840-4.
(569) Kohler, *Am. Chem. J.*, 31, 642-61 (1904).
(570) Schuster, *Ber.*, 63B, 2397-9 (1930).
(571) Geissman, *J. Am. Chem. Soc.*, 62, 1363-7 (1940).
(572) Gomm and Hill, *J. Chem. Soc.*, 1935, 1118-20.
(573) Blicke and Patelski, *J. Am. Chem. Soc.*, 60, 2638-41 (1938).
(574) Kohler and Conant, *J. Am. Chem. Soc.*, 39, 1699-715 (1917).
(575) Fuson, Byers, Rowland, Southwick, and Sperati, *J. Am. Chem. Soc.*, 66, 1873-5 (1944).
(576) Lutz and Reveley, *J. Am. Chem. Soc.*, 63, 3180-9 (1941).
(577) Julian, Cole, Meyer, and Herness, *J. Am. Chem. Soc.*, 67, 1375-81 (1945).
(578) Schlenk and Brauns, *Ber.*, 48, 716-28 (1915).
(579) Lund and Berg, *Kgl. Danske Videnskab. Selskab. Math.-fys. Medd.*, 18, No. 9, 22 pp. (1941); *Chem. Abstr.*, 36, 87 (1942).
(580) Arnold, *J. Am. Chem. Soc.*, 69, 2322-5 (1947).
(581) Reynolds, *Am. Chem. J.*, 46, 198-211 (1911).
(582) Tiffeneau, Lévy, and Weill, *Bull. soc. chim.*, [4], 49, 1709-21 (1931).
(583) Schlenk and Bornhardt, *Ber.*, 46, 1482-3 (1913).
(584) Chu, *J. Chinese Chem. Soc.*, 7, 24-6 (1939).
(585) Koelsch, *J. Am. Chem. Soc.*, 55, 3394-9 (1933).
(586) Shilov and Yudin, *J. Gen. Chem. (U.S.S.R.)*, 9, 167-72 (1939); *Chem. Abstr.*, 33, 6283 (1939).
(587) Gorski, *J. Russ. Phys.-Chem. Soc.*, 45, 163-9 (1913); *Chem. Zentr.*, 1913, 1, 2021.
(588) Tschitschibabin, *Ber.*, 41, 2770-8 (1908).
(589) Schmidlin and Wohl, *Ber.*, 43, 1145-61 (1910).

- (590) Lutz and Reveley, *J. Am. Chem. Soc.*, 63, 3178-80 (1941).
(591) Kohler and Nygaard, *J. Am. Chem. Soc.*, 52, 4128-39 (1930).
(592) Koelsch, *J. Am. Chem. Soc.*, 58, 1331-3 (1935).
(593) French and Smith, *J. Am. Chem. Soc.*, 67, 1949-50 (1945).
(594) Mikeska and Cohen, *J. Org. Chem.*, 6, 787-94 (1941).
(595) Reimer and Reynolds, *Am. Chem. J.*, 40, 428-44 (1908).
(596) Piper and Wright, *J. Am. Chem. Soc.*, 72, 1669-74 (1950).
(597) Ssergejew, *J. Russ. Phys.-Chem. Soc.*, 61, 1421-49 (1929); *Chem. Zentr.*, 1930,II, 391.
(598) Suida and Planckh, *Ber.*, 66B, 1445-54 (1933).
(599) Maxim, *Bull. soc. chim.*, [4], 49, 887-91 (1931).
(600) Pel'kis, *Mem. Inst. Chem. Ukrain. Acad. Sci.*, 3, 45-58 (1936); *Chem. Abstr.*, 31, 4642 (1937).
(601) Pel'kis and Pazenko, *Zapiski Inst. Khim., Akad. Nauk U.R.S.R., Inst. Khim.*, 6, Nos. 3-4, 311-39 (1940); *Chem. Abstr.*, 35, 2469 (1941).
(602) Hahn and Murray, *J. Am. Chem. Soc.*, 36, 1484-97 (1914).
(603) Badoche, *Bull. soc. chim.*, [4], 43, 337-43 (1928).
(604) Jacquemain, *Ann. chim.*, [11], 19, 522-48 (1944).
(605) Kharasch and Lambert, *J. Am. Chem. Soc.*, 63, 2315-6 (1941).
(606) Hurd, Jones, and Blunck, *J. Am. Chem. Soc.*, 57, 2033-6 (1935).
(607) Cason, Adams, Bennett, and Register, *J. Am. Chem. Soc.*, 66, 1764-7 (1944).
(608) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 42, 1490-1 (1910); *Bull. soc. chim.*, [4], 10, 1294 (1911).
(609) Oddo, *Gazz. chim. ital.*, 41,I, 273-94 (1911); *Chem. Abstr.*, 5, 2639 (1911).
(610) Truce and Wise, *J. Am. Chem. Soc.*, 72, 2300 (1950).
(611) Kharasch and Sayles, *J. Am. Chem. Soc.*, 64, 2972-5 (1942).
(612) Mosher and La Combe, *J. Am. Chem. Soc.*, 72, 3994-9 (1950).
(613) Hurd and Cohen, *J. Am. Chem. Soc.*, 53, 1917-22 (1931).
(614) Barré and Repentigny, *Can. J. Research*, 27B, 716-20 (1949).
(615) Dev, *J. Indian Chem. Soc.*, 25, 69-80 (1948).
(616) Dev, *J. Indian Chem. Soc.*, 25, 315-22 (1948).
(617) Bergmann and Bergmann, *J. Am. Chem. Soc.*, 59, 1443-50 (1937).
(618) Swain and Boyles, *J. Am. Chem. Soc.*, 73, 870-2 (1951).
(619) Kharasch and Burt, *J. Org. Chem.*, 16, 150-60 (1951).
(620) Faworsky, *J. prakt. Chem.*, [2], 88, 641-98 (1913).
(621) Herstein, *J. Gen. Chem. (U.S.S.R.)*, 9, 361-8 (1939); *Chem. Zentr.*, 1939,II, 2910.
(622) Alexander and Coraor, *J. Am. Chem. Soc.*, 73, 2721-3 (1951).
(623) Fuson, Emmons, and Tull, *J. Org. Chem.*, 16, 648-51 (1951).
(624) Maxim, *Bul. soc. chim. România*, 12, 24-7 (1930); *Chem. Zentr.*, 1930,II, 3023.
(625) Guyot and Catel, *Bull. soc. chim.*, [3], 35, 551-62 (1906).
(626) Tucker and Whalley, *J. Chem. Soc.*, 1949, 50-5.
(627) Schokina, Kildischeva, and Preobrashenski, *J. Gen. Chem. (U.S.S.R.)*, 11, 425-8 (1941); *Brit. Chem. Abstr.*, A,II, 224 (1942).
(628) Salkind, *J. Russ. Phys.-Chem. Soc.*, 45, 1875-95 (1914); *Bull. soc. chim.*, [4], 16, 536 (1914).
(629) Jones and Weedon, *J. Chem. Soc.*, 1946, 937-9.
(630) Heilbron, *J. Chem. Soc.*, 1948, 386-93.
(631) Blomquist and Marvel, *J. Am. Chem. Soc.*, 55, 1655-62 (1933).
(632) Teterin and Ivanov, *J. Gen. Chem. (U.S.S.R.)*, 7, 1629-31 (1937); *Chem. Abstr.*, 31, 8503 (1937).
(633) Cymerman, Heilbron, Johnson, and Jones, *J. Chem. Soc.*, 1944, 141-4.

- (634) Schmitt, *Ann.*, 547, 115-22 (1941).
(635) Karrer, Salomon, Morf, and Walker, *Helv. Chim. Acta*, 15, 878-89 (1932).
(636) Thompson, Milas, and Rovno, *J. Am. Chem. Soc.*, 63, 752-5 (1941).
(637) Zal'kind, Zonis, and Blokhin, *Compt. rend. acad. sci. U.R.S.S.*, 2, 57-60 (1935); *Chem. Abstr.*, 29, 5819 (1935).
(638) Teterin and Ivanov, *Compt. rend. acad. sci. U.R.S.S.*, 2, 259-60 (1935); *Chem. Abstr.*, 29, 6214 (1935).
(639) Krauze and Slobodin, *J. Gen. Chem. (U.S.S.R.)*, 10, 907-12 (1940); *Chem. Abstr.*, 35, 3237 (1941).
(640) Fuson and Libby, *J. Org. Chem.*, 16, 626-30 (1951).
(641) Lutz and Revely, *J. Am. Chem. Soc.*, 61, 1854-9 (1940).
(642) Fuson and Hornberger, *J. Org. Chem.*, 16, 631-6 (1951).
(643) Heilbron, Johnson, Jones, and Spinks, *J. Chem. Soc.*, 1942, 727-33.
(644) Fuson and Hornberger, *J. Org. Chem.*, 16, 637-42 (1951).
(645) Kohler, *Am. Chem. J.*, 36, 177-95 (1906).
(646) Fuson and Shealy, *J. Org. Chem.*, 16, 643-7 (1951).
(647) Kohler and Bickel, *J. Am. Chem. Soc.*, 57, 1099-101 (1935).
(648) Kayser, *Ann. chim.*, [11], 6, 145-248 (1936).
(649) Bickel, *J. Am. Chem. Soc.*, 59, 325-8 (1937).
(650) Glattfeld and Cameron, *J. Am. Chem. Soc.*, 49, 1043-8 (1927).
(651) Kohler and Potter, *J. Am. Chem. Soc.*, 57, 1316-21 (1935).
(652) Kohler and Larsen, *J. Am. Chem. Soc.*, 57, 1448-52 (1935).
(653) Kohler and Larsen, *J. Am. Chem. Soc.*, 58, 1518-22 (1936).
(654) McBee, Pierce and Higgins, *J. Am. Chem. Soc.*, 74, 1736-7 (1952).
(655) Carré, *Bull. soc. chim.*, [4], 5, 486-9 (1909).
(656) Ford, Thompson, and Marvel, *J. Am. Chem. Soc.*, 57, 2619-23 (1935).
(657) Diels and Johlin, *Ber.*, 44, 403-10 (1911).
(658) Marshall, *J. Chem. Soc.*, 107, 509-23 (1915).
(659) Gaertner, *J. Am. Chem. Soc.*, 74, 2185-8 (1952).
(660) Landrieu and Blatt, *Bull. soc. chim.*, [4], 1424-36 (1924).
(661) Gaertner, *J. Am. Chem. Soc.*, 74, 766-7 (1952).
(662) Harmon and Marvel, *J. Am. Chem. Soc.*, 55, 1716-22 (1933).
(663) Moureu, Dufraisse, and Mackall, *Bull. soc. chim.*, [4], 33, 934-42 (1923).
(664) Moureu, Dufraisse, and Blatt, *Bull. soc. chim.*, [4], 35, 1412-24 (1924).
(665) Haller and Ramart-Lucas, *Compt. rend.*, 159, 143-9 (1914); *Chem. Abstr.*, 8, 3437 (1941).

TABLE VI-XIX
REACTIONS OF GRIGNARD REAGENTS WITH CYCLIC KETONES

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₉OCl			
2-Chlorocyclopentanone	CH ₃ MgX	2-Methylcyclopentanone (poor yield)	201
2-Chlorocyclopentanone	C ₂ H ₅ MgX	2-Ethylcyclopentanone (poor yield)	201
2-Chlorocyclopentanone	<i>i</i> -C ₃ H ₇ MgX	2-Isopropylcyclopentanone (poor yield)	201
2-Chlorocyclopentanone	C ₆ H ₅ MgX	2-Phenylcyclopentanone (poor yield)	201
C₅H₈O			
(CH ₂) ₄ CO	CH ₃ MgI	(CH ₂) ₄ C(CH ₃)OH (65-75%)	359
(CH ₂) ₄ CO (8.4 g.)	CH ₃ MgI (14.2 g. CH ₃ I)	(CH ₂) ₄ C(CH ₃)OH (7.0 g., crude)	319,351
(CH ₂) ₄ CO	CH ₃ MgI	(CH ₂) ₄ C(CH ₃)OH; unidentified product, b.p., 246-248°	269
(CH ₂) ₄ CO (42 g.)	(≡CMgBr) ₂ (12 g. Mg, 55 g. C ₂ H ₅ Br)	[≡CC(OH)(CH ₂) ₄] ₂ (45.2%); HC≡CC(OH)(CH ₂) ₄	344
(CH ₂) ₄ CO	C ₂ H ₅ MgBr	(CH ₂) ₄ C(OH)C ₂ H ₅ (ca. 75%)	350,352
(CH ₂) ₄ CO	C ₂ H ₅ MgI	(CH ₂) ₄ C(OH)C ₂ H ₅	353,354
(CH ₂) ₄ CO (504 g., 6 moles)	H ₂ C=CHCH ₂ Cl (536 g., 7 moles) + Mg (146 g., 6 g.-atoms)	(CH ₂) ₄ C(OH)CH ₂ CH=CH ₂ (54%)*	343
(CH ₂) ₄ CO (122.5 g.)	<i>n</i> -C ₃ H ₇ MgBr (1 equiv.)	(CH ₂) ₄ C(OH)- <i>n</i> -C ₃ H ₇ (107.5 g., crude); (CH ₂) ₄ CHOH; cond'n product	350,352,343
(CH ₂) ₄ CO	<i>i</i> -C ₃ H ₇ MgCl	Ketol (36%)	146
(CH ₂) ₄ CO	<i>i</i> -C ₃ H ₇ MgCl	"Cyclopentenylcyclopentanone" (chief product)	352
(CH ₂) ₄ CO	<i>i</i> -C ₃ H ₇ MgBr	"Cyclopentenylcyclopentanone" (chief product)	352
(CH ₂) ₄ CO (70 g.)	<i>i</i> -C ₃ H ₇ MgI (150 g. C ₃ H ₇ I)	(CH ₂) ₄ C(OH)- <i>i</i> -C ₃ H ₇ (16 g., crude); cond'n product	351,343

* Copper reaction vessel.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₈O (<i>cont.</i>)			
(CH ₂) ₄ CO	H ₂ C=C(CH ₃)CH ₂ Cl + Mg	(CH ₂) ₄ C(OH)CH ₂ C(CH ₃)=CH ₂ (25%)*	343
(CH ₂) ₄ CO	<i>n</i> -C ₄ H ₉ MgBr	(CH ₂) ₄ C(OH)- <i>n</i> -C ₄ H ₉ (<i>ca.</i> 60%); (CH ₂) ₄ CHOH	350,352
(CH ₂) ₄ CO	<i>s</i> -C ₄ H ₉ MgBr	Ketol (42%) [†]	146
(CH ₂) ₄ CO (42 g.)	BrMgO(CH ₃) ₂ CC≡CMgBr (42 g. C ₅ H ₈ O)	HO(CH ₃) ₂ CC≡CC(OH)(CH ₂) ₄	344
(CH ₂) ₄ CO	<i>i</i> -C ₅ H ₁₁ MgBr	(CH ₂) ₄ C(<i>i</i> -C ₅ H ₁₁)OH	124
(CH ₂) ₄ CO	C ₆ H ₅ MgBr	(CH ₂) ₄ C(C ₆ H ₅)OH ("good yield")	313,105
(CH ₂) ₄ CO	BrMgO(CH ₃)(C ₂ H ₅)CC≡CMgBr	(CH ₂) ₄ C(OH)C≡CC(CH ₃)(C ₂ H ₅)OH (43-45%)	106
(CH ₂) ₄ CO (31 g.)	(CH ₂) ₅ CHMgBr (60 g. C ₆ H ₁₁ Br)	(CH ₂) ₄ C(OH)CH(CH ₂) ₅ (21 g.)	314
(CH ₂) ₄ CO	<i>n</i> -C ₆ H ₁₃ MgBr	(CH ₂) ₄ C(<i>n</i> -C ₆ H ₁₃)OH (27%); <i>n</i> -hexylcyclopentene	317
(CH ₂) ₄ CO	<i>n</i> -C ₈ H ₁₇ MgBr	(CH ₂) ₄ C(<i>n</i> -C ₈ H ₁₇)OH	317
(CH ₂) ₄ CO	1-Ethynyl-4-methoxycyclohexanol + C ₂ H ₅ MgBr	1-(1-Hydroxycyclopentyl)-2-(1-hydroxy- 4-methoxycyclohexyl)ethyne	188
(CH ₂) ₄ CO (48.6 g.)	1-C ₁₀ H ₇ MgBr (27.6 ml. C ₁₀ H ₇ Br)	(CH ₂) ₄ C(1-C ₁₀ H ₇)OH, yielding 13.1 g. olefin	26
(CH ₂) ₄ CO	C ₆ H ₅ (CH ₂) ₄ MgCl	(CH ₂) ₄ C[(CH ₂) ₄ C ₆ H ₅]OH (65%)	84
(CH ₂) ₄ CO (8.4 g.)	6-CH ₃ OC ₁₀ H ₆ -2-MgBr (23.7 ml. C ₁₁ H ₉ BrO)	(CH ₂) ₄ C(2-C ₁₀ H ₆ -6-OCH ₃)OH, yielding 15.0 g. olefin	26
(CH ₂) ₄ CO	C ₆ H ₅ (CH ₂) ₅ MgCl	(CH ₂) ₄ C[(CH ₂) ₅ C ₆ H ₅]OH (65%)	84
(CH ₂) ₄ CO (50.4 g.)	1-C ₁₀ H ₇ CH ₂ CH ₂ MgCl (114.0 g., C ₁₂ H ₁₁ Cl)	(CH ₂) ₄ C(CH ₂ CH ₂ -1-C ₁₀ H ₇)OH (85.0 g.)	362
(CH ₂) ₄ CO (8.4 g.)	9-Phenanthryl-MgBr (25.7 ml. C ₁₄ H ₉ Br)	(CH ₂) ₄ C(9-C ₁₄ H ₉)OH (yielding 5.0 g. olefin)	26

* Glass reaction vessel.

[†] Identified as semicarbazone of 2-cyclopentylidenecyclopentanone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₈O (<i>cont.</i>)			
(CH ₂) ₄ CO (10.8 ml.)	9-Phenanthryl-CH ₂ CH ₂ MgCl (29.6 g. C ₁₆ H ₁₃ Cl)	(C ₁₄ H ₉ CH ₂ CH ₂ —) ₂ (1.75 g.); (CH ₂) ₄ C(CH ₂ CH ₂ C ₁₄ H ₉)OH (17.1 g.)	360
C₆H₈O			
2-Cyclohexen-1-one (48.0 g., 0.5 mole)	CH ₃ MgBr (24.3 g., 1.0 g.-atom Mg)	3-Methylcyclohexanone (8.0 g., 15%); 1-methyl-2-cyclohexen-1-ol (38%); condens'n products (18%)	337
2-Cyclohexen-1-one (48.0 g., 0.5 mole)	C ₂ H ₅ MgBr (1.0 mole)	3-Ethylcyclohexanone (15.2 g., 24%); 1-ethyl-2-cyclohexen-1-ol (52%); condens'n products (13%)	337
2-Cyclohexen-1-one (0.5 mole)	C ₂ H ₅ MgBr (1.0 mole C ₂ H ₅ Br)	3-Ethylcyclohexanone (22.8x%)*	338
2-Cyclohexen-1-one (48.0 g., 0.5 mole)	<i>i</i> -C ₃ H ₇ MgCl (1.0 mole)	3-Isopropylcyclohexanone (31.0 g., 44%); 1-isopropyl-2-cyclohexen-1-ol (10%); 2-cyclohexen-1-ol (12%); condens'n products (16%)	337
2-Cyclohexen-1-one (0.5 mole)	<i>i</i> -C ₃ H ₇ MgBr (1.0 mole C ₃ H ₇ Br)	3-Isopropylcyclohexanone (64.5x%)*	338
2-Cyclohexen-1-one (48.0 g., 0.5 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.0 mole)	Recovered ketone (10%); 3- <i>t</i> -butyl- cyclohexanone (70%); condens'n products (14%)	337
2-Cyclohexen-1-one (0.5 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.0 mole C ₄ H ₉ Cl)	3- <i>t</i> -Butylcyclohexanone (61.6x%)*	338
C₆H₈O₂			
Cyclohexane-1,2-dione (112 g.)	CH ₃ MgI (298 g. CH ₃ I)	2-Hydroxy-2-methylcyclohexanone (<i>ca.</i> 95 g., crude)	56

* In this study only the relative yields of 1,4-addition products were evaluated. Total yield of addition products for the reactions studied is said to range from 86 to 100% (*i. e.*, $x = 0.86-1.00$).

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₈O₂ (cont.)			
Dihydroresorcinol* (25 g.)	C ₆ H ₅ MgBr (1 equiv. C ₆ H ₅ Br)	3-Hydroxy-3-phenylcyclohexanone (8 g.); 1-phenylcyclohexen-3-one (15-20 g.); 1,3-diphenyl-1,3-cyclohexadiene (5 g.)	309
C₆H₉OCl			
2-Chlorocyclohexanone	CH ₃ MgI	1-Methyl-2-chlorocyclohexanol	266,46
2-Chlorocyclohexanone	CH ₃ MgI	2-Methylcyclohexanone (2 parts); acetylcylopentane (1 part)	277,266
2-Chlorocyclohexanone	CH ₃ MgI	1-Methyl-2-chlorocyclohexanol (<i>cis</i> and <i>trans</i> chlorohydrins)	267
2-Chlorocyclohexanone	C ₂ H ₅ MgBr	1-Ethyl-2-chlorocyclohexanol	266
2-Chlorocyclohexanone	C ₂ H ₅ MgBr	2-Ethylcyclohexanone; propionylcyclo- pentane (total yield, 50-60%)	276,266
2-Chlorocyclohexanone	C ₂ H ₅ MgBr	1-Ethyl-2-chlorocyclohexanol (<i>cis</i> and <i>trans</i> chlorohydrins)	267
2-Chlorocyclohexanone	<i>i</i> -C ₃ H ₇ MgX	2-Chlorocyclohexanol (27-28% <i>A</i> -isomer; 72-73% <i>B</i> -isomer); (CH ₃) ₂ C=CH ₂ (total yield crude reduction products, 64%)	22
2-Chlorocyclohexanone	<i>n</i> -C ₄ H ₉ MgX [†] (1.5 equiv.)	2- <i>n</i> -Butylcyclohexanone; pentanoylcyclo- pentane (total yield, 27-30%)	275
2-Chlorocyclohexanone	<i>n</i> -C ₄ H ₉ MgBr	1- <i>n</i> -Butyl-2-chlorocyclohexanol (<i>cis</i> and <i>trans</i> chlorohydrins)	267
2-Chlorocyclohexanone	<i>t</i> -C ₄ H ₉ MgCl	2-Chlorocyclohexanol (27-28% <i>A</i> -isomer; 72-73% <i>B</i> -isomer); C ₄ H ₈ (total yield crude reduction products, 72%)	22,342

* A strongly enolic diketone formulated as 3-hydroxycyclohex-2-en-1-one.

[†]X = Br, Cl.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₉OCl (<i>cont.</i>)			
2-Chlorocyclohexanone (280 g.)	C ₆ H ₅ MgBr (750 ml., 3.22 M)	2-Phenylcyclohexanone (58%)	212
2-Chlorocyclohexanone	(CH ₂) ₅ CHMgX	2-Chlorocyclohexanol (27-28% A-isomer; 72-73% B-isomer); C ₆ H ₁₀ (total yield crude reduction products, 27%)	22
C₆H₉ON			
1,5-Dimethyl-2-pyrrolone	CH ₃ MgBr	1,2,5-Trimethylpyrrole*	182
C₆H₁₀O			
2-Methylcyclopentanone	CH ₃ MgI (15% excess)	1,2-Dimethylcyclopentanol	63,361
2-Methylcyclopentanone (17 g.)	CH ₃ O ₂ CCH ₂ Br (25 g.) + Mg (5 g.)	1-Carbomethoxymethyl-2-methylcyclo- hexanol (14 g.)	170
2-Methylcyclopentanone	<i>n</i> -C ₄ H ₉ MgBr	1- <i>n</i> -Butyl-2-methylcyclopentanol	63
2-Methylcyclopentanone (6 g.)	6-CH ₃ OC ₁₀ H ₆ -1-CH ₂ CH ₂ MgCl (12 g. C ₁₃ H ₁₃ ClO)·	1-β-6-Methoxy-1-naphthylethyl)- 2-methylcyclopentanol (6 g.)	363
2-Methylcyclopentanone (7.6 g.)	9-Phenanthryl-CH ₂ CH ₂ MgCl (19.2 g. C ₁₆ H ₁₃ Cl)	1,4-Bis-(9-phenanthryl)butane (1.2 g.); 9-ethylphenanthrene; 1-methyl-2- (β-9-phenanthrylethyl)cyclopentene ("very poor yield")	360
3-Methylcyclopentanone (10 g.)	CH ₃ MgI	1,3-Dimethylcyclopentanol	312,63,313
3-Methylcyclopentanone	C ₂ H ₅ MgI	1-Ethyl-3-methylcyclopentanol	313
3-Methylcyclopentanone	(CH ₂) ₅ CHMgBr	1-Cyclohexyl-3-methylcyclopentanol	314
(CH ₂) ₅ CO	RMgX†	(CH ₂) ₅ CROH	239
(CH ₂) ₅ CO (2.9 g.)	CH ₃ MgI (4.5 g. CH ₃ I)	(CH ₂) ₅ C(CH ₃)OH (2.2 g.)	311
(CH ₂) ₅ CO	CH ₃ MgX	(CH ₂) ₅ C(CH ₃)OH (64%)	255

* The *Chemical Abstracts* report contains a misprint: "1,3,5-" for 1,2,5-.

† R = CH₃, C₂H₅, *n*-C₃H₇, *i*-C₄H₉, *i*-C₅H₁₁, C₆H₅, (CH₂)₅CH, C₆H₅CH₂, 4-CH₃C₆H₄.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₀O (<i>cont.</i>)			
(CH ₂) ₅ CO	(≡CMgBr) ₂	[(CH ₂) ₅ C(OH)C≡] ₂	95
(CH ₂) ₅ CO	(≡CMgI) ₂	[(CH ₂) ₅ C(OH)C≡] ₂	144
(CH ₂) ₅ CO	RMgX*	(CH ₂) ₅ CROH (41-72%)	303
(CH ₂) ₅ CO	C ₂ H ₅ MgX	(CH ₂) ₅ C(C ₂ H ₅)OH (62%)	255
(CH ₂) ₅ CO (34 g.)	BrMgOCH ₂ C≡CMgBr (0.5 mole HOCH ₂ C≡CH)	3-(1-Hydroxycyclohexyl)-2-propyn-1-ol (50% crude)	310
(CH ₂) ₅ CO	2-Thienyl-MgX	1-α-Thienylcyclohexene (91.5%)	105
(CH ₂) ₅ CO	H ₂ C=CHCH ₂ Br + Mg	1-Allylcyclohexanol (81%)	190
(CH ₂) ₅ CO	<i>n</i> -C ₃ H ₇ MgX	(CH ₂) ₅ C(<i>n</i> -C ₃ H ₇)OH (57%)	255
(CH ₂) ₅ CO	<i>i</i> -C ₃ H ₇ MgX	(CH ₂) ₅ C(<i>i</i> -C ₃ H ₇)OH	105
(CH ₂) ₅ CO (19.6 g.)	<i>i</i> -C ₃ H ₇ MgCl	Ketol (3 g.), identified as semicarbazone of corresponding unsat'd ketone (2-cyclo- hexylidenecyclohexanone)	146
(CH ₂) ₅ CO	<i>i</i> -C ₃ H ₇ MgBr	(CH ₂) ₅ C(<i>i</i> -C ₃ H ₇)OH (41%); (CH ₂) ₅ CHOH	255, 281
(CH ₂) ₅ CO	<i>n</i> -C ₄ H ₉ MgX	(CH ₂) ₅ C(<i>n</i> -C ₄ H ₉)OH (48%)	255
(CH ₂) ₅ CO	<i>i</i> -C ₄ H ₉ MgBr	(CH ₂) ₅ CHOH; (CH ₂) ₅ C(<i>i</i> -C ₄ H ₉)OH (10%)	241
(CH ₂) ₅ CO	<i>t</i> -C ₄ H ₉ MgCl	(CH ₂) ₅ C(<i>t</i> -C ₄ H ₉)OH (poor yield); (CH ₂) ₅ CHOH	23
(CH ₂) ₅ CO	<i>n</i> -C ₅ H ₁₁ MgX	(CH ₂) ₅ C(<i>n</i> -C ₅ H ₁₁)OH (54%)	255, 105
(CH ₂) ₅ CO	<i>i</i> -C ₅ H ₁₁ MgX	(CH ₂) ₅ C(<i>i</i> -C ₅ H ₁₁)OH (58%)	255
(CH ₂) ₅ CO	C ₆ H ₅ MgX	(CH ₂) ₅ C(C ₆ H ₅)OH (60%)	255
(CH ₂) ₅ CO	C ₆ H ₅ MgBr	(CH ₂) ₅ C(C ₆ H ₅)OH (85%)	151, 287, 105, 314
(CH ₂) ₅ CO	(CH ₂) ₅ CHMgX	(CH ₂) ₅ C[CH(CH ₂) ₅]OH (53%)	255
(CH ₂) ₅ CO	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CHOH, only	241
(CH ₂) ₅ CO	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ C[CH(CH ₂) ₅]OH (61%)	151, 105
(CH ₂) ₅ CO (8 g.)	C ₆ H ₅ CH ₂ MgCl (12.7 g. C ₇ H ₇ Cl)	(CH ₂) ₅ C(CH ₂ C ₆ H ₅)OH	287
(CH ₂) ₅ CO	2-CH ₃ C ₆ H ₄ MgBr	(CH ₂) ₅ C(C ₆ H ₄ -2-CH ₃)OH (50%)	246

* R = C₂H₅, *n*-C₄H₉, *n*-C₆H₁₃, *n*-C₇H₁₅, *n*-C₈H₁₇, *n*-C₁₂H₂₅.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₀O (cont.)			
(CH ₂) ₅ CO	3-CH ₃ C ₆ H ₄ MgBr	(CH ₂) ₅ C(C ₆ H ₄ -3-CH ₃)OH (48%)	246
(CH ₂) ₅ CO	4-CH ₃ OC ₆ H ₄ MgBr	(CH ₂) ₅ C(C ₆ H ₄ -4-OCH ₃)OH (44%)	246,193
(CH ₂) ₅ CO	4-CH ₃ OC ₆ H ₄ MgBr	(CH ₂) ₅ C(C ₆ H ₄ -4-OCH ₃)OH + 1-anisylcyclohexene (aggregating 73%)	105,151
(CH ₂) ₅ CO	C ₆ H ₅ C≡CMgX	(CH ₂) ₅ C(C≡CC ₆ H ₅)OH (97%)	140
(CH ₂) ₅ CO	C ₆ H ₅ CH(CO ₂ Na)MgX*	C ₆ H ₅ CH(CO ₂ H)C(CH ₂) ₅ OH (80%)	145
(CH ₂) ₅ CO (49 g.)	C ₆ H ₅ CH ₂ CH ₂ MgCl (77 g. C ₆ H ₅ Cl)	(CH ₂) ₅ C(CH ₂ CH ₂ C ₆ H ₅)OH (49 g.)	362
(CH ₂) ₅ CO (30 g.)	C ₆ H ₅ CH ₂ CH ₂ MgCl (42 g. C ₆ H ₅ Cl)	(CH ₂) ₅ C(CH ₂ CH ₂ C ₆ H ₅)OH (40 g.)	358
(CH ₂) ₅ CO	C ₆ H ₅ CH ₂ CH ₂ MgBr	(CH ₂) ₅ C(CH ₂ CH ₂ C ₆ H ₅)OH (54%)	218
(CH ₂) ₅ CO (12 g.)	2,3-(CH ₃) ₂ C ₆ H ₃ MgBr (22 g. C ₆ H ₅ Br)	(CH ₂) ₅ C[C ₆ H ₃ -2,3-(CH ₃) ₂]OH	64
(CH ₂) ₅ CO (17 g.)	3,4-(CH ₃) ₂ C ₆ H ₃ MgBr (32 g. C ₆ H ₅ Br)	(CH ₂) ₅ C[C ₆ H ₃ -3,4-(CH ₃) ₂]OH, (20 g., crude)	64
(CH ₂) ₅ CO (25 g.)	4-C ₂ H ₅ OC ₆ H ₄ MgBr	(CH ₂) ₅ C(C ₆ H ₄ -4-OC ₂ H ₅)OH (19 g.)	193
(CH ₂) ₅ CO	2-CH ₃ O-5-CH ₃ C ₆ H ₃ MgBr	2-CH ₃ O-5-CH ₃ C ₆ H ₃ (HO)CH(CH ₂) ₅ (36%)	246
(CH ₂) ₅ CO (25 g.)	1-C ₁₀ H ₇ MgBr (50 g. C ₁₀ H ₇ Br)	(CH ₂) ₅ C(1-C ₁₀ H ₇)OH (40%)	157,105
(CH ₂) ₅ CO (4.2 g.)	1-C ₁₀ H ₇ MgBr (10.0 g. C ₁₀ H ₇ Br)	1-(1-Cyclohexenyl)naphthalene (6.0 g.)	301,32
(CH ₂) ₅ CO	<i>i</i> -C ₃ H ₇ (CH ₂) ₃ CH(CH ₃)(CH ₂) ₂ MgX	(CH ₂) ₅ C(C ₁₀ H ₂₁)OH (82.5%)	105
(CH ₂) ₅ CO (40 g., 0.4 mole)	4-CH ₃ C ₁₀ H ₆ -1-MgBr (44 g., 0.2 mole C ₁₁ H ₉ Br)	(CH ₂) ₅ C(C ₁₁ H ₉)OH (yielding 50% olefin)	32
(CH ₂) ₅ CO	(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₃ MgCl	(CH ₂) ₅ C[(CH ₂) ₃ N(<i>n</i> -C ₄ H ₉) ₂]OH	189
(CH ₂) ₅ CO	(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₃ Cl + Mg	(CH ₂) ₅ C[(CH ₂) ₃ N(<i>n</i> -C ₄ H ₉) ₂]OH	197
(CH ₂) ₅ CO	CH ₃ (C ₆ H ₅)N(CH ₂) ₃ MgBr	(CH ₂) ₅ C[(CH ₂) ₃ N(CH ₃)C ₆ H ₅]OH; CH ₃ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅)N	290
(CH ₂) ₅ CO	3,4-(CH ₃) ₂ C ₁₀ H ₅ -1-MgBr	(CH ₂) ₅ C[1-C ₁₀ H ₅ -3,4-(CH ₃) ₂]OH (yielding 64% olefin)	32
(CH ₂) ₅ CO	<i>n</i> -C ₁₂ H ₂₅ MgBr	(CH ₂) ₅ C(<i>n</i> -C ₁₂ H ₂₅)OH (74.6%)	105

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₀O (<i>cont.</i>)			
(CH ₂) ₅ CO (23.5 g.)	<i>n</i> -C ₁₂ H ₂₅ MgBr (59 g. C ₁₂ H ₂₅ Br)	(CH ₂) ₅ C(<i>n</i> -C ₁₂ H ₂₅)OH (yielding 25.6 g. olefin)	251
(CH ₂) ₅ CO (10 g.)	9-Phenanthryl-MgBr (25.7 ml. C ₁₄ H ₉ Br)	(CH ₂) ₅ C(C ₁₄ H ₉)OH (yielding 5 g. olefin)	26,105,32
(CH ₂) ₅ CO	<i>n</i> -C ₁₄ H ₂₉ MgX	(CH ₂) ₅ C(<i>n</i> -C ₁₄ H ₂₉)OH (81%)	105
(CH ₂) ₅ CO	<i>n</i> -C ₁₆ H ₃₃ MgX	(CH ₂) ₅ C(<i>n</i> -C ₁₆ H ₃₃)OH (80%)	105
(CH ₂) ₅ CO	<i>n</i> -C ₁₈ H ₃₇ MgX	(CH ₂) ₅ C(<i>n</i> -C ₁₈ H ₃₇)OH (70%)	105
(CH ₂) ₅ CO	<i>i</i> -C ₃ H ₇ (CH ₂) ₃ [CH(CH ₃)(CH ₂) ₃] ₂ -CH(CH ₃)(CH ₂) ₂ MgX	(CH ₂) ₅ C(C ₂₀ H ₄₁)OH (80%)	105
(CH ₂) ₅ CO	<i>n</i> -C ₂₆ H ₅₃ MgX	(CH ₂) ₅ C(<i>n</i> -C ₂₆ H ₅₃)OH (75%)	105
C₆H₁₀O₂			
2,2-Dimethyl-3-tetrahydrofuranone	CH ₃ MgBr	2,2,3-Trimethyl-3-tetrahydrofuranol (60%)	356
2,2-Dimethyl-3-tetrahydrofuranone	C ₂ H ₅ MgBr	2,2-Dimethyl-3-ethyl-3-tetrahydrofuranol	356
2,2-Dimethyl-3-tetrahydrofuranone	C ₆ H ₅ MgBr	2,2-Dimethyl-3-phenyl-3-tetrahydrofuranol (50%)	356
2,2-Dimethyl-3-tetrahydrofuranone	C ₆ H ₅ CH ₂ MgCl	2,2-Dimethyl-3-benzyl-3-tetrahydrofuranol	356
2,2-Dimethyl-3-tetrahydrofuranone	4-CH ₃ C ₆ H ₄ MgBr	2,2-Dimethyl-3- <i>p</i> -tolyl-3-tetrahydrofuranol	356
C₆H₁₁ON			
1-Methyl-2-piperidone	<i>n</i> -C ₃ H ₇ MgBr	<i>N</i> -Methyl- γ -coniceine; * 1-methyl-2,2-dipropylpiperidine	183
1-Methyl-2-piperidone (11.3 g.)	C ₆ H ₅ MgBr (23.5 g. C ₆ H ₅ Br)	1-Methyl-2-hydroxy-2-phenylpiperidine	175,176
1-Methyl-2-piperidone	(CH ₂) ₅ CHMgCl	1-Methyl-2-hydroxy-2-(1-methyl-2-oxo-3-piperidyl)piperidine	175
1-Methyl-2-piperidone (22.6 g.)	C ₆ H ₅ CH ₂ MgBr (34.2 g. C ₇ H ₇ Br)	1-Methyl-2-benzyl-1,4,5,6-tetrahydropyridine	175,176

* 1-Methyl-6-propyl-1,2,3,4-tetrahydropyridine.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₁ON (<i>cont.</i>)			
1-Methyl-2-piperidone (0.2 mole)	4-CH ₃ OC ₆ H ₄ MgBr (0.2 mole C ₇ H ₇ BrO)	1-Methyl-2- <i>p</i> -anisyl-1,4,5,6-tetrahydro-pyridine	175,176
1-Methyl-2-piperidone (37.3 g.)	6-CH ₃ OC ₁₀ H ₆ -2-MgBr (50.0 g. C ₁₁ H ₉ BrO)	1-Methyl-2-(6-methoxy-2-naphthyl)-1,4,5,6-tetrahydropyridine	175,176
1-Methyl-4-piperidone (11.3 g.)	C ₆ H ₅ MgBr (24.0 g. C ₆ H ₅ Br)	1-Methyl-4-phenyl-4-piperidinol	15,2
1-Methyl-4-piperidone (23 g.)	4-CH ₃ OC ₆ H ₄ MgBr (38 g. C ₇ H ₇ BrO)	1-Methyl-4-anisyl-4-piperidinol (10 g.)	322
C₇H₁₀O			
2-Methyl-2-cyclohexen-1-one	CH ₃ MgI	1,2-Dimethyl-2-cyclohexen-1-ol	127
3-Methyl-2-cyclohexen-1-one (22.0 g., 0.2 mole) + CuCl (400 mg.)	CH ₃ MgI (6.5 g., 0.27 g.-atom Mg)	3,3-Dimethylcyclohexanone (15.0 g.)	331
3-Methyl-2-cyclohexen-1-one	H ₂ C=CHCH ₂ Br + Mg	1-Allyl-3-methyl-2-cyclohexen-1-ol (92.7%)	190
3-Methyl-2-cyclohexen-1-one	2-CH ₃ C ₆ H ₄ MgBr	1-Methyl-3- <i>o</i> -tolyl-1,3-cyclohexadiene*	159
3-Methyl-2-cyclohexen-1-one	3-CH ₃ OC ₆ H ₄ (CH ₂) ₂ MgCl (45 g. C ₉ H ₁₁ ClO)	3-Methyl-3'-methoxy-4,5-dihydrobibenzyl (32 g.)	209
C₇H₁₁OCl			
2-Chloro-4-methylcyclohexanone	CH ₃ MgI	2,4-Dimethylcyclohexanone	110
2-Chloro-4-methylcyclohexanone	CH ₃ MgI	1,4-Dimethyl-2-chlorocyclohexanol (<i>cis</i> and <i>trans</i> chlorohydrins)	267
2-Chloro-4-methylcyclohexanone (low-boiling) (117 g., 1.22 mole)	C ₆ H ₅ MgBr (600 ml., 2 M)	Phenylmethylcyclohexanones (150 g., 67%): <i>ca.</i> 3 parts 2-phenyl-4-methyl-, <i>ca.</i> 1 part 2-phenyl-5-methyl	211
2-Chloro-5-methylcyclohexanone	CH ₃ MgI	1,5-Dimethyl-2-chlorocyclohexanol	266

* After sulfuric acid hydrolysis of the Grignard intermediate and distillation of the product.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₁OCl (<i>cont.</i>)			
2-Chloro-5-methylcyclohexanone (liquid)	CH ₃ MgI	2,5-Dimethylcyclohexanone (semicarbazone, m. 155°)	111
2-Chloro-5-methylcyclohexanone (solid)	CH ₃ MgI	2,5-Dimethylcyclohexanone (semicarbazone, m. 122°)	111
2-Chloro-5-methylcyclohexanone	CH ₃ MgI	1,5-Dimethyl-2-chlorocyclohexanol (<i>cis</i> and <i>trans</i> chlorohydrins)	267
C₇H₁₁ON			
1-Methyl-5-ethyl-2-pyrrolone	CH ₃ MgBr	1,2-Dimethyl-5-ethylpyrrole	182
1-Methyl-5-ethyl-2-pyrrolone	C ₂ H ₅ MgBr	1-Methyl-2,5-diethylpyrrole; 1-methyl-2,5,5-triethyl- Δ^2 -pyrroline; (C ₂ H ₅ COCH—) ₂ ; C ₂ H ₆	182
1-Methyl-5-ethyl-2-pyrrolone	C ₆ H ₅ CH ₂ MgCl	1-Methyl-2-ethyl-5-benzylpyrrole (29x%); C ₂ H ₅ CO(CH ₂) ₂ COCH ₂ C ₆ H ₅ (71x%) (Total yield not stated.)	182
C₇H₁₂O			
2,5-Dimethylcyclopentanone	C ₂ H ₅ MgI	1-Ethyl-2,5-dimethylcyclopentanol	314
"Methylcyclohexanone"	(\equiv CMgX) ₂ *	"Glycol" (75%)	142,334
2-Methylcyclohexanone	CH ₃ MgX	1,2-Dimethylcyclohexanol (67%)	255
2-Methylcyclohexanone	CH ₃ MgI	1,2-Dimethylcyclohexanol	23,240,351
2-Methylcyclohexanone	(\equiv CMgBr) ₂	Bis-(1-hydroxy-2-methylcyclohexyl)ethyne	345
2-Methylcyclohexanone	C ₂ H ₅ MgX	1-Ethyl-2-methylcyclohexanol (92%)	255
2-Methylcyclohexanone	C ₂ H ₅ MgI	1-Ethyl-2-methylcyclohexanol (20%)	204
2-Methylcyclohexanone	<i>n</i> -C ₃ H ₇ MgX	1- <i>n</i> -Propyl-2-methylcyclohexanol (57%)	255
2-Methylcyclohexanone	<i>n</i> -C ₃ H ₇ MgI	1- <i>n</i> -Propyl-2-methylcyclohexanol (15%)	204
2-Methylcyclohexanone	H ₂ C=CH(CH ₂) ₂ MgBr	1-(3-Butenyl)-2-methylcyclohexanol (35%)	99

* X = Br, I.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₂O (cont.)			
2-Methylcyclohexanone	<i>n</i> -C ₄ H ₉ MgX	1- <i>n</i> -Butyl-2-methylcyclohexanol (65%)	255
2-Methylcyclohexanone	<i>i</i> -C ₄ H ₉ MgCl	1-Isobutyl-2-methylcyclohexanol	204
2-Methylcyclohexanone	H ₂ C=CH(CH ₂) ₃ MgBr	1-(4-Pentenyl)-2-methylcyclohexanol (57-68%)	97
2-Methylcyclohexanone	<i>n</i> -C ₅ H ₁₁ MgX	1- <i>n</i> -Amyl-2-methylcyclohexanol (63%)	255
2-Methylcyclohexanone	<i>i</i> -C ₅ H ₁₁ MgX	1-Isoamyl-2-methylcyclohexanol	204
2-Methylcyclohexanone	(CH ₂) ₅ CHMgCl	1-Cyclohexyl-2-methylcyclohexanol (which dehydrates on distillation)	204
2-Methylcyclohexanone	C ₆ H ₅ CH ₂ MgCl	1-Benzyl-6-methylcyclohexene	204
2-Methylcyclohexanone (24.6 g.)	C ₆ H ₅ CH ₂ MgCl (25.2 g. C ₇ H ₇ Cl)	1-Benzyl-2-methylcyclohexanol (25 g.)	75
2-Methylcyclohexanone	2-CH ₃ C ₆ H ₄ MgCl	1- <i>o</i> -Tolyl-6-methylcyclohexene	204
2-Methylcyclohexanone (11.5 g.)	C ₆ H ₅ CH ₂ CH ₂ MgCl (14.0 g. C ₈ H ₉ Cl)	1-Phenethyl-2-methylcyclohexanol (7.0 g.)	358
2-Methylcyclohexanone	C ₆ H ₅ CH ₂ CH ₂ MgBr	1-Phenethyl-2-methylcyclohexanol (46%)	218
2-Methylcyclohexanone	1-C ₁₀ H ₇ MgBr	1- α -Naphthyl-2-methylcyclohexanol	74
2-Methylcyclohexanone	<i>n</i> -C ₁₂ H ₂₅ MgBr	1-Dodecyl-2-methylcyclohexanol; "olefin" (<i>i.e.</i> , dehydr'n product)	218
3-Methylcyclohexanone	CH ₃ MgX	1,3-Dimethylcyclohexanol (80%)	255
3-Methylcyclohexanone	CH ₃ MgI	1,3-Dimethylcyclohexanol (90%)	311,240
3-Methylcyclohexanone	(\equiv CMgBr) ₂	1,2-Bis-(1-hydroxy-3-methylcyclo- hexyl)ethyne (93%)	141,345
3-Methylcyclohexanone	HC \equiv CMgBr	1-Ethynyl-3-methylcyclohexanol	143
3-Methylcyclohexanone	C ₂ H ₅ MgX	1-Ethyl-3-methylcyclohexanol (93%)	255
3-Methylcyclohexanone	C ₂ H ₅ MgBr	1-Ethyl-3-methylcyclohexanol (70%)	186
3-Methylcyclohexanone	C ₂ H ₅ MgI	1-Ethyl-3-methylcyclohexanol ("good" yield)	311,312
3-Methylcyclohexanone	<i>n</i> -C ₃ H ₇ MgX	1- <i>n</i> -Propyl-3-methylcyclohexanol (72%)	255
3-Methylcyclohexanone	<i>n</i> -C ₃ H ₇ MgBr	1- <i>n</i> -Propyl-3-methylcyclohexanol ("poor" yield)	186
3-Methylcyclohexanone (16.8 g.)	<i>n</i> -C ₃ H ₇ MgI	1- <i>n</i> -Propyl-3-methylcyclohexanol (9 g.)	311

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₂O (cont.)			
3-Methylcyclohexanone	<i>i</i> -C ₃ H ₇ MgX*	1-Isopropyl-3-methylcyclohexanol; high-boiling hydrocarbons	311
3-Methylcyclohexanone (11.2 g.)	H ₅ C ₂ O ₂ CCH ₂ Br (16.7 g.) + Mg (2.4 g.)	Ethyl α-(1-hydroxy-3-methyl-1-cyclohexyl)acetate (14.0 g.)	315
3-Methylcyclohexanone	<i>n</i> -C ₄ H ₉ MgX	1- <i>n</i> -Butyl-3-methylcyclohexanol (70%)	255
3-Methylcyclohexanone	<i>i</i> -C ₄ H ₉ MgX	1-Isobutyl-3-methylcyclohexanol (6%); 3-methylcyclohexanol	255
3-Methylcyclohexanone	<i>i</i> -C ₄ H ₉ MgCl	1-Isobutyl-3-methylcyclohexanol ("poor" yield)	186
3-Methylcyclohexanone (17.5 g.)	H ₅ C ₂ O ₂ CCH(CH ₃)CH ₂ Br (28.3 g.) + Mg (3.8 g.)	Ethyl α-methyl-β-(1-hydroxy-3-methyl-1-cyclohexyl)propionate (9.0 g., 30%)	315
3-Methylcyclohexanone (28 g.)	H ₅ C ₂ O ₂ CCH(CH ₃)CH ₂ I (55 g.) + Mg (6 g.)	Ethyl α-methyl-β-(1-hydroxy-3-methyl-1-cyclohexyl)propionate (24 g., 45%)	315
3-Methylcyclohexanone	<i>i</i> -C ₅ H ₁₁ MgBr	1-Isoamyl-3-methylcyclohexanol (70%)	186
3-Methylcyclohexanone	C ₆ H ₅ MgBr	1-Phenyl-3-methylcyclohexanol (yield "considerable")	186
3-Methylcyclohexanone	(CH ₂) ₅ CHMgCl	1-Cyclohexyl-3-methylcyclohexanol ("satisfactory" yield)	186
3-Methylcyclohexanone (28 g.)	H ₅ C ₂ O ₂ CCH(C ₂ H ₅)CH ₂ Br (29 g.) + Mg (6 g.)	Ethyl α-ethyl-β-(1-hydroxy-3-methyl-1-cyclohexyl)propionate (31 g., 50%)	315
3-Methylcyclohexanone	C ₆ H ₅ CH ₂ MgCl	1-Benzyl-3-methylcyclohexanol ("poor" yield)	186
3-Methylcyclohexanone (11.5 g.)	C ₆ H ₅ CH ₂ CH ₂ MgCl (14.0 g. C ₈ H ₉ Cl)	1-Phenethyl-3-methylcyclohexanol (10.0 g.)	358
3-Methylcyclohexanone	1-C ₁₀ H ₇ MgBr	1-α-Naphthyl-3-methylcyclohexanol	36
3-Methylcyclohexanone	<i>n</i> -C ₁₂ H ₂₅ MgBr	1-Dodecyl-3-methylcyclohexanol; "olefin" (i.e., dehydr'n product)	219

* X = Br, I.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₂O (cont.)			
4-Methylcyclohexanone	CH ₃ MgI	1,3-Dimethylcyclohexanol ("very good" yield)	240,242,294
4-Methylcyclohexanone	C ₂ H ₅ MgX	1-Ethyl-4-methylcyclohexanol (69%)	255
4-Methylcyclohexanone	C ₂ H ₅ MgI	1-Ethyl-4-methylcyclohexanol ("good" yield)	242
4-Methylcyclohexanone	<i>n</i> -C ₃ H ₇ MgX	1- <i>n</i> -Propyl-4-methylcyclohexanol (52%)	255
4-Methylcyclohexanone	<i>n</i> -C ₃ H ₇ MgX	1- <i>n</i> -Propyl-4-methylcyclohexanol; 4-methylcyclohexanol	242
4-Methylcyclohexanone	<i>i</i> -C ₃ H ₇ MgI	1-Isopropyl-4-methylcyclohexanol ("very little"); 4-methylcyclohexanol	242,217
4-Methylcyclohexanone	<i>n</i> -C ₄ H ₉ MgX	1- <i>n</i> -Butyl-4-methylcyclohexanol	255
4-Methylcyclohexanone	<i>i</i> -C ₄ H ₉ MgBr	4-Methylcyclohexanol; C ₄ H ₈	242
4-Methylcyclohexanone	<i>i</i> -C ₅ H ₁₁ MgBr	1-Isoamyl-4-methylcyclohexanol ("a little"); 4-methylcyclohexanol	242
4-Methylcyclohexanone	C ₆ H ₅ MgBr	1-Phenyl-4-methylcyclohexanol	242
4-Methylcyclohexanone	C ₆ H ₅ CH ₂ MgCl	1-Benzyl-4-methylcyclohexanol ("good" yield)	242
4-Methylcyclohexanone (11.5 g.)	C ₆ H ₅ CH ₂ CH ₂ MgCl (14.0 g., C ₆ H ₅ Cl)	1-Phenethyl-4-methylcyclohexanol (9.0 g.)	358
4-Methylcyclohexanone	"Secondary" C ₈ H ₁₇ MgI	"1- <i>s</i> -Octyl-4-methylcyclohexanol" (25%)	242
4-Methylcyclohexanone	1-C ₁₀ H ₇ MgBr	1- α -Naphthyl-4-methylcyclohexanol	36
(CH ₂) ₆ CO*	CH ₃ MgI	(CH ₂) ₆ C(CH ₃)OH	291
(CH ₂) ₆ CO* (11 g.)	CH ₃ MgI (28 g. CH ₃ I)	1-Methylcycloheptene (b. 74-75 °/100 mm.) (88 g.)	236
(CH ₂) ₆ CO*	(\equiv CMgI) ₂	[(CH ₂) ₆ C(OH)C \equiv] ₂	144
(CH ₂) ₆ CO*	H ₅ C ₂ O ₂ CCCH ₂ Br (17.0 g.) + Mg (2.5 g.)	Ethyl α -(1-hydroxycycloheptyl)acetate (11.0 g.)	315
(CH ₂) ₆ CO*	C ₆ H ₅ CH ₂ MgCl	1-Benzylcycloheptanol	96

* Suberone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₂O₂			
4-Methoxycyclohexanone	C ₂ H ₅ MgBr	1-Ethyl-4-methoxycyclohexanol (60%)	188
4-Methoxycyclohexanone	1-Ethynylcyclohexanol + C ₂ H ₅ MgBr	1,1'-Dihydroxy-4-methoxydicyclohexyl-ethyne (78%, crude; 2 isomers)	188
4-Methoxycyclohexanone	1-Ethynyl-4-methoxycyclohexanol + C ₂ H ₅ MgBr	Bis-(1-hydroxy-4-methoxycyclohexyl)ethyne	188
3-Methylcyclohexan-1-ol-2-one	CH ₃ MgI	2,3-Dimethylcyclohexanone	172
C₈H₄O₂BrN			
5-Bromoïsatin*	CH ₃ MgI	3-Hydroxy-3-methyl-5-bromoöxindole †	167
5-Bromoïsatin	C ₆ H ₅ MgBr	3-Hydroxy-3-phenyl-5-bromoöxindole	167
C₈H₅O₂N			
Isatin ‡	CH ₃ MgI	3-Hydroxy-3-methyloxindole §	167
Isatin	RMgBr ¶ (2.5 equiv.)	3-Hydroxy-3-R-oxindole	166
Isatin	C ₆ H ₅ MgBr	3-Hydroxy-3-phenyloxindole	139
Isatin	2-CH ₃ C ₆ H ₄ MgI	3-Hydroxy-3- <i>o</i> -tolylloxindole	139
Isatin	3-CH ₃ C ₆ H ₄ MgI	3-Hydroxy-3- <i>m</i> -tolylloxindole	139
Isatin	4-CH ₃ C ₆ H ₄ MgI	3-Hydroxy-3- <i>p</i> -tolylloxindole	139
Isatin	2-CH ₃ OC ₆ H ₄ MgI	3-Hydroxy-3- <i>o</i> -methoxyphenyloxindole	139
Isatin	3-CH ₃ OC ₆ H ₄ MgI	3-Hydroxy-3- <i>m</i> -methoxyphenyloxindole	139
Isatin	4-CH ₃ OC ₆ H ₄ MgI	3-Hydroxy-3- <i>p</i> -anisylloxindole	139

* 5-Bromo-2,3-indolinedione; 5-bromoïsatic acid lactam.

† 3-Hydroxy-3-methyl-5-bromo-2(3*H*)-indolone.

‡ 2,3-Indolinedione; isatic acid lactam.

§ 3-Hydroxy-3-methyl-2(3*H*)-indolone.

¶ R = 4-BrC₆H₄, C₆H₅, C₆H₅CH₂, 1-C₁₀H₇.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₇OCl₃			
4-Methyl-4-trichloromethyl-2,5-cyclohexadien-1-one	CH ₃ MgI	1,4-Dimethyl-4-trichloromethyl-2,5-cyclohexadien-1-ol (80-90%)	323
C₈H₈OCl₂			
4-Methyl-4-dichloromethyl-2,5-cyclohexadien-1-one (19.1 g.)	CH ₃ MgI (14.2 g. CH ₃ I)	1,4-Dimethyl-4-dichloromethyl-2,5-cyclohexadien-1-ol (8 g. or less)	283,282
4-Methyl-4-dichloromethyl-2,5-cyclohexadien-1-one	C ₂ H ₅ MgI (2 equiv.)	1-Ethyl-4-methyl-4-dichloromethyl-2,5-cyclohexadien-1-ol	278
4-Methyl-4-dichloromethyl-2,5-cyclohexadien-1-one	<i>n</i> -C ₃ H ₇ MgX* (2 equiv.)	1- <i>n</i> -Propyl-4-methyl-4-dichloromethyl-2,5-cyclohexadien-1-ol (<i>ca.</i> quant.)	279
4-Methyl-4-dichloromethyl-2,5-cyclohexadien-1-one	<i>i</i> -C ₃ H ₇ MgBr	1-Isopropyl-4-methyl-4-dichloromethyl-2,5-cyclohexadien-1-ol (<i>ca.</i> quant.)	279
4-Methyl-4-dichloromethyl-2,5-cyclohexadien-1-one	C ₆ H ₅ CH ₂ MgCl (2 equiv.)	1-Benzyl-4-methyl-4-dichloromethyl-2,5-cyclohexadien-1-ol	279
C₈H₁₂O			
2,3-Dimethyl-2-cyclohexen-1-one (12.5 g.)	C ₆ H ₅ (CH ₂) ₂ MgCl (14.2 g. C ₆ H ₅ Cl)	1,2-Dimethyl-3-phenethyl-1,3-cyclohexadiene (6 g.)	35
2,3-Dimethyl-2-cyclohexen-1-one (9.2 g.)	3-CH ₃ OC ₆ H ₄ (CH ₂) ₂ MgCl (11.0 g. C ₉ H ₁₁ ClO)	1,2-Dimethyl-3- <i>m</i> -methoxyphenethyl-1,3-cyclohexadiene (7.5 g.)	35
3,5-Dimethyl-2-cyclohexen-1-one (1.00 mole)	CH ₃ MgI (1.05 mole)	1,3,5-Trimethyl-2-cyclohexen-1-ol	346
3,5-Dimethyl-2-cyclohexen-1-one	C ₂ H ₅ MgBr (2 equiv.)	1-Ethyl-3,5-dimethyl-2-cyclohexen-1-ol	346
3,5-Dimethyl-2-cyclohexen-1-one	H ₂ C=CHCH ₂ Br + Mg	1-Allyl-3,5-dimethyl-2-cyclohexen-1-ol (95%)	190
3,5-Dimethyl-2-cyclohexen-1-ol	<i>i</i> -C ₃ H ₇ MgBr (2 equiv.)	1-Isopropyl-3,5-dimethyl-2-cyclohexen-1-ol	346
3,5-Dimethyl-2-cyclohexen-1-one (25 g.)	C ₆ H ₅ MgBr	3,5-Dimethyl-1-phenyl-2-cyclohexen-1-ol (36 g., pure)	164,287

*X = Br, I.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₂O (<i>cont.</i>)			
<i>cis</i> -Bicyclo[3.3.0]octan-2-one (15.0 g.)	C ₆ H ₅ CH ₂ MgCl (15.5 g. C ₇ H ₇ Cl)	2-Benzyl- <i>cis</i> -bicyclo[3.3.0]octan-2-ol (12.4 g.); liquid isomer (6.1 g.)	21
4-Methyl-4-dichloromethylcyclohexanone	CH ₃ MgI	1,4-Dimethyl-4-dichloromethylcyclohexanol (<i>ca.</i> quant.)	286
C₈H₁₂O₂			
Tetramethyl-1,3-cyclobutanedione (15.0 g., 0.106 mole)	CH ₃ MgBr (60.0 g. CH ₃ Br)	(CH ₃) ₂ CO (0.8 g.); (<i>i</i> -C ₃ H ₇) ₂ CO (1.8 g.); HO(CH ₃) ₂ CC(CH ₃) ₂ CO- <i>i</i> -C ₃ H ₇ (12 g., 65%)	98
Tetramethyl-1,3-cyclobutanedione (4.2 g.)	C ₂ H ₅ MgBr (7.0 g. C ₂ H ₅ Br)	1,3-Diethyl-2,2,4,4-tetramethyl-1,3-cyclobutanediol* (<i>ca.</i> quant.)	296
Tetramethyl-1,3-cyclobutanedione (20.0 g.)	C ₂ H ₅ MgBr (85.0 g. C ₂ H ₅ Br)	C ₂ H ₅ CH(OH)C(CH ₃) ₂ CO- <i>i</i> -C ₃ H ₇ (21.8 g., 84%) [†]	98
Tetramethyl-1,3-cyclobutanedione (12.0 g.)	C ₂ H ₅ MgBr (11.0 g. C ₂ H ₅ Br)	Recovered ketone (7.3 g., 60%); C ₂ H ₅ CH(OH)C(CH ₃) ₂ CO- <i>i</i> -C ₃ H ₇ (3.8 g., 83% on basis of ketone consumed) [‡]	98
Tetramethyl-1,3-cyclobutanedione (21.0 g.)	C ₆ H ₅ MgBr (119.6 g. C ₆ H ₅ Br)	(<i>i</i> -C ₃ H ₇) ₂ CO (14.5 g., 85%); (C ₆ H ₅) ₂ CO (26.1 g., 95%) [§]	98
Tetramethyl-1,3-cyclobutanedione (12.0 g.)	C ₆ H ₅ MgBr (16.8 g. C ₆ H ₅ Br)	Recovered ketone (7.1 g., 59%); (<i>i</i> -C ₃ H ₇) ₂ CO (2.1 g., 53% on basis of ketone consumed); (C ₆ H ₅) ₂ CO (5.8 g., 91%) [†]	98
Tetramethyl-1,3-cyclobutanedione (5.0 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (23.0 g., C ₉ H ₁₁ Br)	Recovered ketone (4.2 g., 84%)	98

* According to Erickson and Kitchens (98), this product, erroneously characterized, is actually C₂H₅CH(OH)C(CH₃)₂CO-*i*-C₃H₇.

[†] Portionwise addition of ketone to Grignard reagent solution; fifteen minutes reflux.

[‡] Slow (forty-five minutes) addition of Grignard reagent solution to Et₂O-ketone solution.

[§] Portionwise addition of ketone to Grignard reagent solution.

[†] Slow (one hour) addition of Grignard reagent solution to Et₂O-ketone solution.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₂O₂ (cont.)			
Dihydroresorcinol enol ethyl ether*	RMgX [†] (1.58 equiv.)	3-R-2-Cyclohexen-1-one (12-85%)	307
Dihydroresorcinol enol ethyl ether* (70 g.)	C ₆ H ₅ MgBr (0.75 mole)	3-Phenyl-2-cyclohexen-1-one (71 g., 87%)	309
Dihydroresorcinol enol ethyl ether* (92.0 g.)	3-C ₆ H ₅ C ₆ H ₄ MgBr (114.6 g. C ₁₂ H ₉ Br)	3-(3-Biphenyl)-2-cyclohexen-1-one (70.0 g., crude)	308
Dimedone [‡] (50 g., 0.35 mole)	C ₆ H ₅ MgBr (1.5 mole C ₆ H ₅ Br)	1-Phenyl-5,5-dimethylcyclohexen-3-one (21.5 g., 31%); 1,3-diphenyl-5,5-dimethyl-1,3-cyclohexadiene (15.9 g., 18%); tar (10-20 g.)	307
C₈H₁₂O₂Br₂			
2,2,5,5-Tetramethyl-4,4-dibromotetrahydrofuran-3-one	C ₂ H ₅ MgBr	2,2,5,5-Tetramethyl-4-bromotetrahydrofuran-3-one; 2,2,5,5-tetramethyl-4-bromo-4-ethyltetrahydrofuran-3-one (20%)	222
C₈H₁₂O₃			
3-Carboethoxycyclopentanone (15.6 g.)	6-CH ₃ OC ₁₀ H ₆ -2-MgBr (18.0 g. C ₁₁ H ₉ BrO)	3-Hydroxy-3-(6-methoxy-2-naphthyl)cyclopentanecarboxylic acid lactone (9.0 g., crude)	223
C₈H₁₃ON			
1-Oxoöctahydropyrrocoline [§] (1.85 g.)	CH ₃ MgI (13.5 g. CH ₃ I)	1-Hydroxy-1-methyloctahydropyrrocoline (1.28 g.)	72

* Formulated as 3-ethoxy-2-cyclohexen-1-one.

[†] The Grignard reagents studied and the corresponding yields of the indicated products are as follows: CH₃, 34%; C₂H₅, 75%; *i*-C₃H₇, 12%; *n*-C₄H₉, 85%; *i*-C₄H₉, 43%; *s*-C₄H₉, 15%; *t*-C₄H₉, 13%.

[‡] 5,5-Dimethyl-1,3-cyclohexanedione.

[§] 1-Oxoindolizidine, 1-oxopiperolidine.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₃ON (<i>cont.</i>)			
2-Oxo δ octahydropyrrocoline	C ₂ H ₅ MgI	2-Hydroxy-2-ethyloctahydropyrrocoline ("very good" yield)	72
C₈H₁₃O₂Br			
2,2,5,5-Tetramethyl-4-bromo- tetrahydrofuran-3-one	C ₂ H ₅ MgBr	2,2,5,5-Tetramethyltetrahydrofuran-3-one (chiefly); 2,2,5,5-Tetramethyl-4-ethyl- tetrahydrofuran-3-one (20%)	222
C₈H₁₄O			
2-Methyl-4-ethylcyclopentanone (30.0 g.)	C ₆ H ₅ MgBr (56.3 g. C ₆ H ₅ Br)	1-Phenyl-2-methyl-5-ethylcyclopentanol (18.0 g., 37%); recovered ketone (16.0 g., 53%)	263
2-Ethylcyclohexanone (20 g.)	<i>n</i> -C ₄ H ₉ MgBr (23 g. C ₄ H ₉ Br)	1- <i>n</i> -Butyl-2-ethylcyclohexanol (20 g.)	152
2,2-Dimethylcyclohexanone	CH ₃ MgI	1,2,2-Trimethylcyclohexanol (<i>ca.</i> quant.)	286
2,3-Dimethylcyclohexanone (6.0 g.)	CH ₃ MgI (11.3 g. CH ₃ I)	1,2,3-Trimethylcyclohexanol	285
2,5-Dimethylcyclohexanone	<i>i</i> -C ₃ H ₇ MgI	2,5-Dimethylcyclohexanol	242
2,6-Dimethylcyclohexanone	3- <i>i</i> -C ₃ H ₇ C ₆ H ₄ (CH ₂) ₂ MgBr	1-(<i>m</i> -Isopropylphenethyl)-2,6- dimethylcyclohexanol	44
3,3-Dimethylcyclohexanone	CH ₃ MgBr	1,3,3-Trimethylcyclohexanol (70%)	81
3,3-Dimethylcyclohexanone	C ₂ H ₅ MgBr	1-Ethyl-3,3-dimethylcyclohexanol	81
3,5-Dimethylcyclohexanone	CH ₃ MgI	1,3,5-Trimethylcyclohexanol	294
(CH ₂) ₇ CO	C ₆ H ₅ MgBr	(CH ₂) ₇ C(C ₆ H ₅)OH + 1-phenylcyclo δ tene (aggregating 73.5%)	
(CH ₂) ₇ CO	<i>n</i> -C ₁₈ H ₃₇ MgBr	(CH ₂) ₇ C(<i>n</i> -C ₁₈ H ₃₇)OH (70%)	105
C₈H₁₄O₂			
2,2,5,5-Tetramethyl-3-tetrahydro- furanone	CH ₃ MgBr	2,2,3,5,5-Pentamethyl-3-tetrahydrofuranol	356

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₄O₂ (cont.)			
2,2,5,5-Tetramethyl-3-tetrahydrofuranone	CH ₃ MgI	2,2,3,5,5-Pentamethyl-3-tetrahydrofuranol	355
2,2,5,5-Tetramethyl-3-tetrahydrofuranone	(≡ CMgBr) ₂	[≡ CC(OH)(C ₇ H ₁₄ O)] ₂	355
2,2,5,5-Tetramethyl-3-tetrahydrofuranone	C ₂ H ₅ MgBr	2,2,5,5-Tetramethyl-3-ethyl-3-tetrahydrofuranol (40-50%)	222
2,2,5,5-Tetramethyl-3-tetrahydrofuranone	H ₂ C=CHCH ₂ MgBr	2,2,5,5-Tetramethyl-3-allyl-3-tetrahydrofuranol	356
2,2,5,5-Tetramethyl-3-tetrahydrofuranone	C ₆ H ₅ CH ₂ MgBr	2,2,5,5-Tetramethyl-3-benzyl-3-tetrahydrofuranol	356
2,2,5,5-Tetramethyl-3-tetrahydrofuranone	RMgX*	Enolate	356
C₉H₄OBr₃			
2,3-Dibromo-1-indone (10.0 g.)	CH ₃ MgI (5.8 g. CH ₃ I)	1-Methyl-2,3-dibromo-1-indenol (3.7 g.)	256
2,3-Dibromo-1-indone	C ₂ H ₅ MgBr (2 equiv.)	1-Ethyl-2,3-dibromo-1-indenol (85%)	256
C₉H₄OBrI			
2-Iodo-3-bromo-1-indone	CH ₃ MgI	1-Methyl-2-iodo-3-bromoinden-1-ol (81%)	256
C₉H₇O₂N			
1-Methylisatin (0.05 mole)	C ₆ H ₅ MgBr (0.25 mole)	1-Methyl-2,3-epoxy-2,3-diphenylindoline (ca. 52%); 1-methyl-3,3-diphenyloxindole	206
C₉H₈O			
Indone	CH ₃ MgI	1-Methyl-1-indanol	289,262,162

* RMgX = "most Grignard reagents."

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₈O (<i>cont.</i>)			
Indone (66 g.)	H ₂ C=CH(CH ₂) ₃ MgBr	1-(Δ^4 -Pentenyl)-1-indanol (53 g.)	187
Indone (13.5 g.)	9-Phenanthryl-MgBr (25.7 ml. C ₁₄ H ₉ Br)	1-(9-Phenanthryl)-1-indanol + correspond- ing olefin (aggregating (10.0 g.)	26
2-Indanone	CH ₃ MgI	2-Methyl-2-indanol (73%)	162
C₉H₁₀OCl₂			
2,4-Dimethyl-4-dichloromethyl- 2,5-cyclohexadien-1-one	CH ₃ MgI	1,2,4-Trimethyl-4-dichloromethyl-2,5-cyclo- hexadien-1-ol	284
2,4-Dimethyl-4-dichloromethyl- 2,5-cyclohexadien-1-one	C ₂ H ₅ MgI	1-Ethyl-2,4-dimethyl-4-dichloromethyl- 2,5-cyclohexadien-1-ol	284
3,4-Dimethyl-4-dichloromethyl- 2,5-cyclohexadien-1-one	CH ₃ MgI	1,3,4-Trimethyl-4-dichloromethyl-2,5- cyclohexadien-1-ol	284
3,4-Dimethyl-4-dichloromethyl- 2,5-cyclohexadien-1-one	C ₂ H ₅ MgI	1-Ethyl-3,4-dimethyl-4-dichloromethyl- 2,5-cyclohexadien-1-ol	284
C₉H₁₄O			
4-Isopropyl-2-cyclohexen-1-one	CH ₃ MgI	1-Methyl-4-isopropyl-2-cyclohexen-1-ol; α -Phellandrene (1-methyl-4-isopropyl- 1,5-cyclohexadiene)	293
3-Methyl-5-ethyl-2-cyclohexen- 1-one	H ₂ C=CHCH ₂ Br + Mg	1-Allyl-3-methyl-5-ethyl-2-cyclohexen-1-ol (99.2%)	190
Isophorone*	CH ₃ MgBr	1,3,5,5-Tetramethyl-2-cyclohexen-1-ol (42.6%); 1,3,5,5-tetramethyl-1,3-cyclo- hexadiene (48.2%) [†]	153

* 3,5,5-Trimethyl-2-cyclohexen-1-one.

[†] Slow addition of Et₂O-ketone solution to stirred Grignard reagent solution at 10–20°; one hour heating; overnight standing.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₄O (<i>cont.</i>)			
Isophorone*	CH ₃ MgBr	1,3,5,5-Tetramethyl-2-cyclohexen-1-ol (67.2%); 1,3,5,5-tetramethylcyclohexadiene (23.6) [†]	153
Isophorone* (50 g.)	CH ₃ MgBr (2 equiv.)	1,3,5,5-Tetramethyl-1,3-cyclohexadiene (43 g.)	250
Isophorone* + CuCl (1 mole-%)	CH ₃ MgBr	1,3,5,5-Tetramethylcyclohexadiene (6.9%); 3,3,5,5-tetramethylcyclohexanone (82.5%)	153
Isophorone* (1.5 mole)	CH ₃ MgBr (2.0 moles)	Recovered ketone (10%); 1,3,5,5-tetramethyl-2-cyclohexen-1-ol (83%)	337
Isophorone*	C ₂ H ₅ MgBr	Recovered ketone (10%); 1-ethyl-3,5,5-trimethyl-2-cyclohexen-1-ol (80%)	337
Isophorone*	<i>i</i> -C ₃ H ₇ MgBr	3,5,5-Trimethyl-3-isopropylcyclohexanone (8%)	337
Isophorone* (17.2 g.)	<i>n</i> -C ₄ H ₉ C≡CMgBr (12.5 g. C ₆ H ₁₀)	1-(1-Hexynyl)-3,5,5-trimethyl-2-cyclohexen-1-ol (10.1 g.)	347
Sabinaketone [‡]	CH ₃ MgI	Sabinene hydrate [§]	249
Camphenilone [¶]	(≡CMgBr) ₂	[C ₈ H ₁₄ =C(OH)C≡] ₂ (35.4%)	94
Camphenilone [¶]	<i>n</i> -C ₃ H ₇ MgBr	Camphenilol||	179
Nopinone**	CH ₃ MgI	Pinene hydrate ^{††} (80%)	292

* 3,5,5-Trimethyl-2-cyclohexen-1-one.

[†] Addition of Grignard reagent solution to Et₂O-ketone solution.[‡] 5-Isopropylbicyclo[3.1.0]hexan-2-one.[§] 2-Methyl-5-isopropylbicyclo[3.1.0]hexan-2-ol.[¶] 2,2-Dimethylbicyclo[2.2.1]heptan-3-one.^{||} 2,2-Dimethylbicyclo[2.2.1]heptan-3-ol.

** 6,6-Dimethylbicyclo[3.1.1]heptan-2-one.

^{††} Homopinol; 2,6,6-trimethylbicyclo[3.1.1]heptan-2-ol.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₄O (<i>cont.</i>)			
Nopinone*	C ₂ H ₅ MgI	Ethylnopinol [†]	292
α-Fenchocamphorone [‡]	CH ₃ MgI	2,7,7-Trimethylbicyclo[2.2.1]heptan-2-ol	169
C₉H₁₄O₃			
2-Carbethoxymethylcyclopentanone	CH ₃ MgX	2-Hydroxy-2-methylcyclopentaneacetic acid γ-lactone	336
2-Methyl-2-carbethoxycyclopentanone	C ₂ H ₅ O ₂ CCH ₂ Br + Mg	Ethyl α-(1-hydroxy-2-methyl-2-carbethoxycyclopentyl)acetate	99
C₉H₁₅ON			
2-Oxoöctahydropyridocoline [§]	CH ₃ MgI	2-Hydroxy-2-methyloctahydropyridocoline ("extremely small yield")	72
C₉H₁₇ON			
2-Dimethylaminomethylcyclohexanone	4-CH ₃ OC ₆ H ₄ MgBr	1-Anisyl-2-dimethylaminomethylcyclohexanol	175
2-Dimethylaminomethylcyclohexanone (14.1 g.)	2-(1-Tetralylidene)ethyl-MgBr (22.9 g. C ₁₂ H ₁₃ Br)	1-[2-(1-Tetralylidene)ethyl]-2-dimethylaminomethylcyclohexanol; (C ₁₂ H ₁₉) ₂	89
1-Butyl-4-piperidone (15.5 g.)	C ₆ H ₅ MgBr (23.5 g. C ₆ H ₅ Br)	1-Butyl-4-phenyl-4-piperidinol (8 g.)	322
Triacetoneamine [¶]	C ₂ H ₅ MgI	2,2,6,6-Tetramethyl-4-ethyl-4-piperidinol	70
C₉H₁₇O₂N			
2-Dimethylaminomethyl-3-hydroxycyclohexanone	CH ₃ MgI	1-Methyl-2-dimethylaminomethylcyclohexane-1,3-diol	90

* 6,6-Dimethylbicyclo[3.1.1]heptan-2-one.

[†] 2-Ethyl-6,6-dimethylbicyclo[3.1.1]heptan-2-ol.[‡] 7,7-Dimethylbicyclo[2.2.1]heptan-2-one.[§] 2-Oxoöctahydro-4-quinazoline, 2-oxoöctahydro-4-pyrido[1.2-a]pyridine, 2-oxonorlupinane.[¶] 2,2,6,6-Tetramethyl-4-piperidone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₇O₂N (<i>cont.</i>)			
2-Dimethylaminomethyl-5-hydroxy-cyclohexanone	CH ₃ MgI	1-Methyl-2-dimethylaminomethylcyclohexane-1,5-diol	90
C₁₀H₈O			
2-Methyl-1-indenone	CH ₃ MgI (excess)	1,2-Dimethyl-1-indenol	262
C₁₀H₉O₂N			
1-Ethylisatin	<i>n</i> -C ₄ H ₉ MgBr (1 equiv.)	1-Ethyl-3-hydroxy-3- <i>n</i> -butyloxindole ("good yield")	264
1-Ethylisatin	<i>n</i> -C ₄ H ₉ MgBr (4 equiv.)	1-Ethyl-2,3-dibutyl-2,3-epoxyindoline	264
1-Ethylisatin	C ₆ H ₅ MgBr (5 equiv.)	1-Ethyl-2,3-diphenyl-2,3-epoxyindoline (56%); 1-ethyl-3,3-diphenyloxindole (16%)	206
C₁₀H₁₀O			
2-Methyl-1-indanone (5.0 g.)	CH ₃ MgI (7.3 g. CH ₃ I)	1,2-Dimethyl-1-indanol (4.0 g.)	262,289
3-Methyl-1-indanone	CH ₃ MgI	1,3-Dimethylindone	289
α -Tetralone*	4-BrC ₆ H ₄ MgBr	1- <i>p</i> -Bromophenyl-1-tetralol	288
α -Tetralone	C ₆ H ₅ MgBr	1-Phenyl-1-tetralol	288
α -Tetralone (50 g.)	C ₆ H ₅ MgBr (61.5 g. C ₆ H ₅ Br)	1-Phenyl-3,4-dihydronaphthalene (28 g.)	301
α -Tetralone (36.5 g.)	(CH ₂) ₅ CHMgCl (30 g. C ₆ H ₁₁ Cl)	Recovered ketone (21.5 g.); 1-cyclohexyl-1-tetralol and 1-cyclohexyl-3,4-dihydronaphthalene (yielding 3.8 g. hydrocarbon on complete dehydr'n); 1-oxo-2-(1-tetralylidene)-1,2,3,4-tetrahydronaphthalene (?) (3.7 g.)	77,36
α -Tetralone	4-CH ₃ C ₆ H ₄ MgBr	1- <i>p</i> -Tolyl-1-tetralol	288
α -Tetralone	4-CH ₃ OC ₆ H ₄ MgBr	1-Anisyl-1-tetralol	193

* 3,4-Dihydro-1(2*H*)-naphthalenone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₀O (<i>cont.</i>)			
α -Tetralone (15.0 g.)	C ₆ H ₅ CH ₂ CH ₂ MgCl (14.0 g. C ₈ H ₉ Cl)	1-Phenethyl-1-tetralol (9.5 g.)	358
α -Tetralone (8.8 g.)	2-C ₁₀ H ₇ MgBr (15 g. C ₁₀ H ₇ Br)	1- β -Naphthyl-1-tetralol (yielding 11.3 g. hydrocarbon)	134,216
α -Tetralone (9.0 g.)	9-Phenanthryl-MgBr (15 ml. C ₁₄ H ₉ Br)	1-(9-Phenanthryl)-1-tetralol (yielding 1.0 g. hydrocarbon)	26
C₁₀H₁₂OCl₂			
2,4,5-Trimethyl-4-dichloromethyl-2,5-cyclohexadien-1-one	CH ₃ MgI	1,2,4,5-Tetramethyl-4-dichloromethyl-2,5-cyclohexadien-1-ol	284
C₁₀H₁₄O			
Carvone*	CH ₃ MgX [†]	1,2-Dimethyl-5-isopropenyl-2-cyclohexen-1-ol (<i>ca.</i> quant.)	156,227,280
Carvone*	CH ₃ MgI	2,3-Dimethyl-5-isopropenyl-1,3-cyclohexadiene; 2,3-dimethyl-5-isopropenylcyclohexanone	229
Carvone* (15.2 g.) + CuBr (0.1 g.)	CH ₃ MgI (16.0 g. CH ₃ I)	2,3-Dimethyl-5-isopropenylcyclohexanone (11.0 g.); diene (?) (2.5 g.)	330
Carvone*	(\equiv CMgBr) ₂	Glycol, m.p. 145-147°	334
Carvone* (30 g.)	C ₂ H ₅ MgBr (50 g. C ₂ H ₅ Br)	1-Ethyl-2-methyl-5-isopropenyl-2-cyclohexen-1-ol (27 g.)	156
Carvone* (12.0 g.)	<i>n</i> -C ₃ H ₇ MgBr (12.5 g.)	1- <i>n</i> -Propyl-2-methyl-5-isopropenyl-2-cyclohexen-1-ol (11.0 g.)	155
Carvone*	<i>i</i> -C ₅ H ₁₁ MgBr	2-Methyl-3-isoamyl-5-isopropenylcyclohexanone; 1-isoamyl-2-methyl-5-isopropenyl-2-cyclohexen-1-ol	245

* 2-Methyl-5-isopropenyl-2-cyclohexen-1-one; 6,8(9)-*p*-menthadien-2-one.[†]X = Br, I.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₄O (<i>cont.</i>)			
Carvone* (30 g.)	C ₆ H ₅ MgBr (50 g. C ₆ H ₅ Br)	1-Phenyl-2-methyl-5-isopropenyl-2-cyclohexen-1-ol	155
Carvone*	C ₆ H ₅ CH ₂ MgCl	2-Methyl-3-benzyl-5-isopropenylcyclohexanone; 2 isomeric hydrocarbons (C ₁₇ H ₂₀)	230
Carvone*	CH ₃ (C ₆ H ₅)CHMgBr	C ₁₈ H ₂₀	230
Pinocarvone † (150 g., 1.0 mole)	CH ₃ MgX † (1.2 mole CH ₃ X †)	Ethylapopinocampone § (95.9%, crude)	335
Pinocarvone † (150 g., 1.0 mole)	C ₂ H ₅ MgBr (1.2 mole)	<i>n</i> -Propylapopinocampone (88%, crude)	335
Pinocarvone † (150 g., 1.0 mole)	<i>n</i> -C ₃ H ₇ MgBr (1.2 mole)	<i>n</i> -Butylapopinocampone (82%, crude)	335
Pinocarvone † (150 g., 1.0 mole)	<i>i</i> -C ₃ H ₇ MgBr (1.2 mole)	<i>i</i> -Butylapopinocampone (45%, crude)	335
Pinocarvone † (150 g., 1.0 mole)	<i>n</i> -C ₄ H ₉ MgBr (1.2 mole)	<i>n</i> -Amylapopinocampone (68%, crude)	335
Pinocarvone † (150 g., 1.0 mole)	C ₆ H ₅ MgBr (1.2 mole)	Benzylapopinocampone (55%, crude)	335
Pinocarvone † (150 g., 1.0 mole)	C ₆ H ₅ CH ₂ MgCl (1.2 mole)	Resinous products, only	335
3,4,5,6,7,8-Hexahydro-1(2 <i>H</i>)-naphthalenone	CH ₃ MgCl	1-Methyl-1,2,3,4,5,6,7,8-octahydro-1-naphthol	125
4,4a,5,6,7,8-Hexahydro-2(3 <i>H</i>)-naphthalenone (12.0 g.) + CuBr (0.2 g.)	CH ₃ MgI (19.5 g. CH ₃ I)	<i>cis</i> -8a-Methyl-2-decalone (5.0 g.)	330
Cyclopentenocycloheptan-4-one (20 g.)	CH ₃ MgI (35 g. CH ₃ I)	4-Methyl-1,2,3,6,7,8-hexahydrocyclopentacycloheptane (12 g.)	244
Cyclopentenocycloheptan-4-one (40.0 g.)	C ₂ H ₅ MgBr (60.0 g. C ₂ H ₅ Br)	4-Ethyl-1,2,3,6,7,8-hexahydrocyclopentacycloheptane (25.6 g.)	244

* 2-Methyl-5-isopropenyl-2-cyclohexen-1-one; 6,8(9)-*p*-menthadien-2-one.

† 2-Methylene-6,6-dimethylbicyclo[3.1.1]heptan-3-one.

‡ X = Br, I.

§ 2-Ethyl-6,6-dimethylbicyclo[3.1.1]heptan-3-one.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₄O (<i>cont.</i>)			
Cyclopentenocycloheptan-4-one (20 g.)	C ₆ H ₅ MgBr (45 g. C ₆ H ₅ MgBr)	4-Phenyl-1,2,3,6,7,8-hexahydrocyclo- pentacycloheptane + 4-phenyl-4-cyclo- pentenocycloheptanol (totaling 20 g.)	244
C₁₀H₁₄O₂			
DL-Camphorquinone* (15 g.)	C ₆ H ₅ MgBr (25 g. C ₆ H ₅ Br)	Product, m. 193° (8.4 g., 38%); product, m. 114-115° (9.5 g.); (C ₆ H ₅ —) ₂	119
DL-Camphorquinone*	C ₆ H ₅ MgBr	2-Hydroxy-2-phenylepicamphor; 3-hydroxy-3-phenylcamphor	120
DL-Camphorquinone* (40 g.)	1-C ₁₀ H ₇ MgBr	3-Hydroxy-3- α -naphthylcamphor (12 g., 17%)	119
2-Hydroxycarvone [†] (20 g.)	C ₂ H ₅ MgBr (35 g. C ₂ H ₅ Br)	2-Ethylcarvone [‡]	268
C₁₀H₁₅O₃			
2-Carboxymethylcyclohexanone (10 g.)	C ₆ H ₅ (CH ₂) ₂ MgBr (10 g. C ₆ H ₅ Br)	2-Hydroxy-2-phenethylcyclohexylacetic acid lactone (7 g.)	115
C₁₀H₁₆O			
Dihydrocarvone [§]	CH ₃ MgI	<i>t</i> -Methyldihydrocarveol [¶] (87%)	227
Carvenone|| (45.5 g.)	CH ₃ MgI (58.5 g. CH ₃ I)	2-Methylcarvenol; ** 2-methyl- α -terpinene ^{††}	228

* Camphane-2,3-dione; 3-oxocamphor.

[†] 2-Methyl-3-hydroxy-5-isopropenyl-2-cyclohexen-1-one.[‡] 2-Methyl-3-ethyl-5-isopropenyl-2-cyclohexen-1-one.[§] 2-Methyl-5-isopropenylcyclohexanone.[¶] 2,3-Dimethyl-5-isopropenylcyclohexanol.^{||} 2-Methyl-5-isopropyl-5-cyclohexen-1-one; 3-*p*-menthen-2-one.** 1,2-Dimethyl-5-isopropyl-5-cyclohexen-1-one; 2-methyl-3-*p*-menthadien-2-ol.^{††} 1,2-Dimethyl-4-isopropyl-1,3-cyclohexadiene.

TABLE VI-XIX (Continued)

Ketone	RMgX	Product(s)	Ref.
C₁₀H₁₆O (cont.)			
Pulegone*	CH ₃ MgI	C ₁₁ H ₁₈	116,228,280
Pulegone*	CH ₃ MgI	<i>t</i> -Methylpulegol †	117
Pulegone*	H ₂ C=CHCH ₂ Br + Mg	<i>t</i> -Allylpulegol (ca. 90%)	147
Pulegone* (100 g.)	<i>i</i> -C ₅ H ₁₁ MgBr (150 g. C ₅ H ₁₁ Br)	Recovered ketone (75 g.); <i>t</i> -isomylpulegol (ca. 8 g.); 8-isoamylmenthone ‡ (ca. 12 g.)	92
Isopulegone §	CH ₃ MgI	<i>t</i> -Methylisopulegol ¶	190
3-Methyl-5- <i>n</i> -propyl-2-cyclohexen-1-one	H ₂ C=CHCH ₂ Br + Mg	1-Allyl-3-methyl-5- <i>n</i> -propyl-2-cyclohexen-1-ol (97.1%)	190
3-Methyl-5-isopropyl-2-cyclohexen-1-one	H ₂ C=CHCH ₂ Br + Mg	1-Allyl-3-methyl-5-isopropyl-2-cyclohexen-1-ol (91.2%)	190
<i>trans</i> -2-Decalone (120 g.)	H ₂ C=CH(CH ₂) ₂ MgBr (105 g. C ₄ H ₇ Br)	<i>trans</i> -2-(Δ ³ -Butenyl)-2-decalol (25 g., purified)	99
<i>trans</i> -2-Decalone (15.0 g.)	C ₆ H ₅ CH ₂ MgCl (12.5 g. C ₇ H ₇ Cl)	<i>trans</i> -2-Benzyl-2-decalol (16.0 g.)	76
<i>trans</i> -2-Decalone	3-CH ₃ -4-CH ₃ OC ₆ H ₃ (CH ₂) ₂ MgCl	<i>trans</i> -2-(3-Methyl-4-methoxyphenethyl)-2-decalol	78
Fenchone ‖	CH ₃ MgI	<i>t</i> -Methylfenchol**	311,50
Fenchone ‖	(≡CMgBr) ₂	[C ₉ H ₁₆ =C(OH)C≡] ₂ (20%)	94
Fenchone ‖	C ₂ H ₅ MgI	<i>t</i> -Ethylfenchol; fenchyl alcohol	171
Fenchone ‖	C ₆ H ₅ MgBr	<i>t</i> -Phenylfenchol (7%)	306
Fenchone ‖	C ₆ H ₅ MgBr †† (4 equiv.)	<i>t</i> -Phenylfenchol (36%)	328

* 2-Isopropylidene-5-methylcyclohexanone; 4(8*H*)-*p*-menthen-3-one.

† 1,5-Dimethyl-2-isopropylidenecyclohexanol.

‡ 2-(2,5-Dimethyl-2-hexyl)-5-methylcyclohexanone.

§ 3-Methyl-6-isopropenylcyclohexanone.

¶ 1,3-Dimethyl-6-isopropenylcyclohexanol.

‖ 1,3,3-Trimethylbicyclo[2.2.1]heptan-2-one.

** 1,2,3,3-Tetramethylbicyclo[2.2.1]heptan-2-ol.

†† Reaction at 110-120° in Bu₂O.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₆O (<i>cont.</i>)			
Fenchone*	C ₆ H ₅ CH ₂ MgCl	<i>t</i> -Benzylfenchol (45%)	306
Fenchone*	2-CH ₃ C ₆ H ₄ MgBr	<i>t</i> -o-Tolylfenchol	306
Fenchone*	4-CH ₃ C ₆ H ₄ MgBr	<i>t</i> -p-Tolylfenchol	306
Isofenchone [†] (10.0 g.)	CH ₃ MgI (12.3 g. CH ₃ I)	<i>t</i> -Methylisofenchol [†] (5.0 g.)	168
Camphor§	CH ₃ MgI	<i>t</i> -Methylborneol [¶]	311,49
Camphor§	(≡MgBr) ₂	[C ₉ H ₁₆ =C(OH)C≡] ₂ (35.8%)	94,144
Camphor§	H ₂ C=CHCH ₂ MgBr	<i>t</i> -Allylborneol	208
Camphor§	H ₂ C=CHCH ₂ Br + Mg	<i>t</i> -Allylborneol	66,147
Camphor§	<i>n</i> -C ₃ H ₇ MgBr	Borneol and isoborneol [‡]	179
Camphor§	C ₆ H ₅ MgBr	<i>t</i> -Phenylborneol	49
Camphor§	1-C ₁₀ H ₇ MgBr	<i>t</i> -α-Naphthylborneol	49
Camphor§	α-Camphoryl-MgBr	2-Hydroxy-2-(2-oxo-3-camphanyl)camphane	185
Camphor§	(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₃ Cl + Mg	<i>t</i> -3-(Di- <i>n</i> -butylaminopropyl)borneol	197
Epicamphor** (20 g.)	CH ₃ MgI (25 g. CH ₃ I)	<i>t</i> -Methylepiborneol ^{††} (30-40%)	214
<i>cis</i> -Bicyclo[5.3.0]decan-4-one (4.9 g.)	CH ₃ MgI	4-Methyl- <i>cis</i> -bicyclo[5.3.0]decan-4-ol (5.1 g., 94%)	260
<i>cis</i> -Bicyclo[5.3.0]decan-5-one (19.1 g.)	CH ₃ MgI (48.0 g. CH ₃ I)	5-Methyl- <i>cis</i> -bicyclo[5.3.0]decan-5-ol (87%)	259

* 1,3,3-Trimethylbicyclo[2.2.1]heptan-2-one.

[†] 1,3,3-Trimethylbicyclo[2.2.1]heptan-6-one.[‡] 1,3,3,6-Tetramethylbicyclo[2.2.1]heptan-6-ol.

§ 1,7,7-Trimethylbicyclo[2.2.1]heptan-2-one.

[¶] 1,2,7,7-Tetramethylbicyclo[2.2.1]-heptan-2-ol.[‡] (-)- and (+)-1,7,7-Trimethylbicyclo[2.2.1]heptan-2-ol.

** 1,7,7-Trimethylbicyclo[2.2.1]heptan-3-one.

^{††} 1,3,7,7-Tetramethylbicyclo[2.2.1]heptan-3-ol.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₆O₂			
2-Ketocineole*	CH ₃ MgI	2-Hydroxy-2-methylcineole [†] (2 isomers)	327
2-Ketocineole*	C ₂ H ₅ MgI	2-Hydroxy-2-ethylcineole (2 isomers)	327
2-Ketocineole*	C ₆ H ₅ MgBr	2-Hydroxy-2-phenylcineole (2 isomers)	327
Dimedone enol ethyl ether [‡] (84 g., 0.5 mole)	C ₆ H ₅ MgBr (1 mole C ₆ H ₅ Br)	3-Phenyl-5,5-dimethyl-2-cyclohexen-1-one (74 g., 74%)	307
C₁₀H₁₆O₃			
2-Carboxymethylcyclohexanone	C ₆ H ₅ MgBr	1-Phenyl-2-carboxymethylcyclohexanol	62
2-Methyl-2-carboxycyclohexanone	C ₆ H ₅ (CH ₂) ₂ MgBr	1-Phenethyl-6-methyl-6-carboxycyclohexene (after dehydr'n)	129
C₁₀H₁₈O			
Tetrahydrocarvone § (38.5 g.)	C ₆ H ₅ CH ₂ MgCl (40 g. C ₇ H ₇ Cl)	1-Benzyl-2-methyl-5-isopropylcyclohexanol (43 g.)	76
Tetrahydrocarvone § (31 g.)	1-C ₁₀ H ₇ (CH ₂) ₂ MgCl (47 g. C ₁₁ H ₁₁ Cl)	1-[β-(α-Naphthyl)ethyl]-2-methyl-5-isopropylcyclohexan-1-ol (10 g. crude)	78
Menthone ¶	CH ₃ MgI	C ₁₂ H ₂₀	116
Menthone ¶	CH ₃ MgI	<i>t</i> -Methylmenthol [‡] (75.5%)	295,312
Menthone ¶	HC≡CMgBr	<i>t</i> -Ethynylmenthol	143
Menthone	H ₂ C=CHCH ₂ Br + Mg	<i>t</i> -Allylmenthol (ca. 90%)	147
(-)- or DL-Menthone	C ₆ H ₅ MgBr	<i>t</i> -Phenylmenthol	205

* 1,3,3-Trimethyl-2-oxabicyclo[2.2.2]octan-6-one.

[†] 1,3,3,6-Tetramethyl-2-oxabicyclo[2.2.2]octan-6-ol.[‡] 3-Ethoxy-5,5-dimethyl-2-cyclohexen-1-one.

§ 2-Methyl-5-isopropylcyclohexanone.

¶ 2-Isopropyl-5-methylcyclohexanone.

[‡] 1,3-Dimethyl-6-isopropylcyclohexanol.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₈O (<i>cont.</i>)			
(-)- or DL-Menthone	(CH ₃) ₅ CHMgCl	<i>t</i> -Cyclohexylmenthol	205
2,2,6,6-Tetramethylcyclohexanone (15 g.)	CH ₃ MgI (1 equiv.)	1,2,2,6,6-Pentamethylcyclohexanol (12 g.)	79
C₁₀H₁₈O₂			
"Dimethyldiethyltetrahydrofuran- 2-one"	RMgX	Enolate (quant.)	356
C₁₀H₁₉ON			
1,2,2,6,6-Pentamethyl-4- piperidone (16.9 g.)	C ₆ H ₅ MgBr (24.0 g. C ₆ H ₅ Br)	1,2,2,6,6-Pentamethyl-4-hydroxy-4- phenylpiperidine	15
C₁₁H₁₀O			
1-Phenyl-1-cyclopenten-3-one (5 g.)	CH ₃ MgI (8.6 g. CH ₃ I)	1-Phenyl-3-methyl-1,3-cyclopentadiene (3.5 g.)	45
1-Phenyl-1-cyclopenten-3-one	C ₂ H ₅ MgBr	1-Phenyl-3-ethyl-1,3-cyclopentadiene	45
1-Phenyl-1-cyclopenten-3-one	C ₆ H ₅ MgBr	1,3-Diphenyl-1,3-cyclopentadiene	45
2-Methyl-1-indenone (2.2 g.)	CH ₃ MgI (4.2 g. CH ₃ I)	1,2-Dimethyl-1-indenol	289
C₁₁H₁₀O₂			
2,2-Dimethyl-1,3-indandione (2.0 g.)	C ₆ H ₅ MgBr (1.8 g. C ₆ H ₅ Br)	2,2-Dimethyl-3-hydroxy-3-phenyl-1- indanone (20%)	300
2,2-Dimethyl-1,3-indandione (4 g.)	C ₆ H ₅ MgBr (1 equiv.)	2,2-Dimethyl-3-hydroxy-3-phenyl-1- indanone; 1,3-diphenyl-2,2-dimethyl- 1,3-indandiol*	108
2,2-Dimethyl-1,3-indandione (4 g.)	C ₆ H ₅ MgBr (3 equiv.)	1,3-Diphenyl-2,2-dimethyl-1,3-indandiol (6.5 g., 86%) [†]	108

* Addition of Grignard reagent solution to Et₂O-ketone solution; two hours standing.

[†] Gradual (fifteen minutes) addition of Grignard reagent solution to C₆H₆-ketone solution; three hours standing.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₀O₂ (cont.)			
2,2-Dimethyl-1,3-indandione (20 g., 0.11 mole)	C ₆ H ₅ MgBr (0.03 mole)	2,2-Dimethyl-3-hydroxy-3-phenyl-1-indanone (5.7 g., 75%); recovered ketone (13 g.)*	108
2,2-Dimethyl-1,3-indandione (8 g.)	C ₆ H ₅ MgBr (0.025 mole)	1,3-Diphenyl-2,2-dimethyl-1,3-indandiol (79%) [†]	108
C₁₁H₁₂O			
3,3-Dimethyl-1-indanone (10.0 g.)	C ₆ H ₅ MgBr (14.4 ml. C ₆ H ₅ Br)	1-Phenyl-3,3-dimethyl-1-indanol (9.5 g.)	33
2-Methyl- α -tetralone [‡] (2.9 g.)	C ₂ H ₅ MgBr (1.9 g. C ₂ H ₅ Br)	1-Ethyl-2-methyl-3,4-dihydronaphthalene (1.5 g.)	51
5-Methyl- α -tetralone [§] (1.0 g.)	<i>n</i> -C ₃ H ₇ MgI (3.3 g. C ₃ H ₇ I)	1- <i>n</i> -Propyl-5-methyl-1,2,3,4-tetrahydro-1-naphthol (1.3 g.)	126
5-Methyl- α -tetralone [§]	β -(5-Methyl-1,2,3,4-tetrahydro-1-naphthyl)ethyl-MgBr	α -(5-Methyl-1,2,3,4-tetrahydro-1-naphthyl)- β -(5-methyl-3,4-dihydronaphthyl)ethane	234
7-Methyl- α -tetralone [¶]	CH ₃ MgX	1,7-Dimethyl-1,2,3,4-tetrahydro-1-naphthol (<i>ca.</i> 70%)	20
7-Methyl- α -tetralone [¶] (7 g.)	C ₂ H ₅ MgBr (6 g. C ₂ H ₅ Br)	1-Ethyl-7-methyl-3,4-dihydronaphthalene (6 g.)	51
7-Methyl- α -tetralone [¶]	<i>i</i> -C ₃ H ₇ MgX	1-Isopropyl-7-methyl-1,2,3,4-tetrahydro-1-naphthol (<i>ca.</i> 70%)	20
6-Methyl- β -tetralone|| (2.0 g.)	CH ₃ MgI (5.4 g. CH ₃ I)	2,6-Dimethyl-1,2,3,4-tetrahydro-2-naphthol (1.5 g.)	224,225

* Slow (two to three hours) dropwise addition of Grignard reagent solution to cooled C₆H₆-ketone solution; overnight standing.

[†] Addition of Grignard reagent solution to C₆H₆-ketone solution; partial distillation of Et₂O; sixteen hours at 80°; addition of excess Grignard reagent.

[‡] 2-Methyl-3,4-dihydro-1(2*H*)-naphthalenone.

[§] 5-Methyl-3,4-dihydro-1(2*H*)-naphthalenone.

[¶] 7-Methyl-3,4-dihydro-1(2*H*)-naphthalenone.

^{||} 6-Methyl-3,4-dihydro-2(1*H*)-naphthalenone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₂O₂			
6-Methoxy- α -tetralone*	H ₅ C ₂ O ₂ CCH ₂ CH ₂ X [†] (1 equiv.) + Mg (1 equiv.)	β -(6-Methoxy-3,4-dihydro-1-naphthyl)propionic acid	121
7-Methoxy- α -tetralone [‡]	CH ₃ MgI	1-Methyl-7-methoxy-1,2,3,4-tetrahydro-1-naphthol [§]	131
7-Methoxy- α -tetralone [‡] (27.0 g.)	CH ₃ MgI (22.0 ml. CH ₃ I)	1-Methyl-7-methoxy-3,4-dihydronaphthalene (21.5 g.)	202
C₁₁H₁₆O			
4a-Methyl-4,4a,5,6,7,8-hexahydro-2(3 <i>H</i>)-naphthalenone (2.4 g.) + CuBr (0.05 g.)	CH ₃ MgI (3.0 g. CH ₃ I)	4a,8a-Dimethyl-2-decalone (120 mg.)	330
<i>cis</i> -8a-Methyl-1-decalone	C ₂ H ₅ O(CH ₂) ₃ MgBr	1- γ -Ethoxypropyl-8a-methyl-1-decalol	17
C₁₁H₁₈O			
3-Methyl-5-isobutyl-2-cyclohexen-1-one	H ₂ C=CHCH ₂ Br + Mg	1-Allyl-3-methyl-5-isobutyl-2-cyclohexen-1-ol (98%)	190
C₁₁H₁₈O₃			
2,6-Dimethyl-2-carbethoxycyclohexanone	C ₆ H ₅ (CH ₂) ₂ MgBr	After dehydr'n, 1-Phenethyl-2,6-dimethyl-6-carbethoxycyclohexene	129
2,6-Dimethyl-2-carbethoxycyclohexanone	4-CH ₃ OC ₆ H ₄ (CH ₂) ₂ MgCl	1- <i>p</i> -Methoxyphenethyl-2,6-dimethyl-2-carbethoxycyclohexanol; 1- <i>p</i> -methoxyphenethyl-2,6-dimethyl-6-carbethoxycyclohexene	37

* 6-Methoxy-3,4-dihydro-1(2*H*)-naphthalenone.[†] X = Cl, Br.[‡] 7-Methoxy-3,4-dihydro-1(2*H*)-naphthalenone.[§] Isolated, after dehydration and dehydrogenation, as 1-methyl-7-methoxynaphthalene (22.5 g. from 26.0 g. ketone).

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₈O₃ (<i>cont.</i>)			
2,6-Dimethyl-2-carbethoxycyclohexanone	3- <i>i</i> -C ₃ H ₇ C ₆ H ₄ (CH ₂) ₂ MgBr	After dehydr'n, 1- <i>m</i> -Isopropylphenethyl-2,6-dimethyl-6-carbethoxycyclohexene	129
C₁₁H₁₉O₃N			
2-Dimethylaminomethyl-3-acetoxycyclohexanone	2-(1-Decalylidene)ethyl-MgBr	1-(2- α -Decalylidenethyl)-2-dimethylaminomethyl-3-acetoxycyclohexanol	91
2-Dimethylaminomethyl-5-acetoxycyclohexanone	2-(1-Decalylidene)ethyl-MgBr	1-(2- α -Decalylidenethyl)-2-dimethylaminomethyl-5-acetoxycyclohexanol	91
C₁₂H₁₂O			
3-Phenyl-2-cyclohexen-1-one (10.0 g.)	C ₆ H ₅ MgBr (18.3 g. C ₆ H ₅ Br)	1,3-Diphenyl-1,3-cyclohexadiene (14.0 g., crude)	310
C₁₂H₁₄O			
2-Phenylcyclohexanone (118 g.)	C ₂ H ₅ MgBr (78 g. C ₂ H ₅ Br)	1-Ethyl-2-phenylcyclohexanol (117.4 g., 85%); gas (1.3 l.)	215
2-Ethyl- α -tetralone* (3.0 g.)	CH ₃ MgI (2.9 g. CH ₃ I)	1-Methyl-2-ethyl-3,4-dihydronaphthalene (2.4 g.)	51
2-Ethyl- α -tetralone* (78.8 g.)	C ₂ H ₅ MgBr (98.0 g. C ₂ H ₅ Br)	1,2-Diethyl-1,2,3,4-tetrahydronaphthol (90.5 g., 98%)	158
2,5-Dimethyl- α -tetralone [†]	C ₂ H ₅ MgI (10 equiv.)	1-Ethyl-2,5-dimethyl-1,2,3,4-tetrahydro-1-naphthol; dehydr'n product	232

* 2-Ethyl-3,4-dihydro-1(2*H*)-naphthalenone.[†] 2,5-Dimethyl-3,4-dihydro-1(2*H*)-naphthalenone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₁₄O (<i>cont.</i>)			
2,7-Dimethyl- α -tetralone*	C ₂ H ₅ MgI (10 equiv.)	1-Ethyl-2,7-dimethyl-1,2,3,4-tetrahydro-1-naphthol; dehydr'n product	232
5,6-Dimethyl- α -tetralone †	2-(5-Methyl-1,2,3,4-tetrahydro-1-naphthyl)ethyl-MgBr	1-(5-Methyl-1,2,3,4-tetrahydro-1-naphthyl)-2-(5,6-dimethyl-3,4-dihydro-1-naphthyl)ethane	234
5,6-Dimethyl- α -tetralone †	2-(7-Methyl-1,2,3,4-tetrahydro-1-naphthyl)ethyl-MgBr	1-(7-Methyl-1,2,3,4-tetrahydro-1-naphthyl)-2-(5,6-dimethyl-3,4-dihydro-1-naphthyl)ethane	234
5,6-Dimethyl- α -tetralone †	2-(5,6-Dimethyl-1,2,3,4-tetrahydro-1-naphthyl)ethyl-MgBr	1-(5,6-Dimethyl-1,2,3,4-tetrahydro-1-naphthyl)-2-(5,6-dimethyl-3,4-dihydro-1-naphthyl)ethane	234
6,7-Dimethyl- α -tetralone ‡	CH ₃ MgX	1,6,7-Trimethyl-1,2,3,4-tetrahydro-1-naphthol (<i>ca.</i> 70%)	20
C₁₂H₁₄O₂			
2-Methyl-6-furfurylidene-cyclohexanone	C ₆ H ₅ MgBr	1-Methyl-6-(phenyl- α -furylmethyl)-cyclohexanone	305
2-Methyl-6-furfurylidene-cyclohexanone	C ₆ H ₅ CH ₂ MgCl	1-Methyl-6-[1-(α -furyl)-2-phenylethyl]cyclohexanone	305
2-Methyl-6-furfurylidene-cyclohexanone	4-CH ₃ C ₆ H ₄ MgBr	1-Methyl-6-(phenyl- <i>p</i> -tolylmethyl)cyclohexanone	305
2-Methyl-7-methoxy- α -tetralone § (10.0 g.)	CH ₃ MgI (4.5 ml. CH ₃ I)	1,2-Dimethyl-7-methoxy-1,2,3,4-tetrahydro-1-naphthol + 1,2-dimethyl-7-methoxy-3,4-dihydronaphthalene (totaling 8.0 g.)	203

* 2,7-Dimethyl-3,4-dihydro-1(2*H*)-naphthalenone.† 5,6-Dimethyl-3,4-dihydro-1(2*H*)-naphthalenone.‡ 6,7-Dimethyl-3,4-dihydro-1(2*H*)-naphthalenone.§ 2-Methyl-7-methoxy-3,4-dihydro-1(2*H*)-naphthalenone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₁₅ON			
2-(α -Piperidylmethyl)cyclohexanone	3-CH ₃ OC ₆ H ₄ MgBr	1-(<i>m</i> -Methoxyphenyl)-2-(α -piperidylmethyl)cyclohexanol (30%)	175
C₁₂H₁₈O			
2-Ethylcarvone*	C ₂ H ₅ MgBr	2,6-Diethylmenthatriene [†]	268
$\Delta^{1(7)}$ -Bicyclo[5.5.0]dodecen-2-one (5.0 g.)	CH ₃ MgI (11.8 g. CH ₃ I)	2-Methylbicyclo[5.5.0]dedecadiene (probably $\Delta^{2,12(1)}$) (3.0 g. 60%)	52
C₁₂H₂₀O			
2,8-Dimethylbicyclo[5.3.0]decan-5-one (2.7 g.)	CH ₃ MgI (4.0 CH ₃ I)	2,5,8-Trimethylbicyclo[5.3.0]decan-5-ol	220
2,8-Dimethylbicyclo[5.3.0]decan-5-one (1.0 g.)	<i>i</i> -C ₃ H ₇ MgBr (1.4 g. C ₃ H ₇ Br)	"Dihydroguaiaene"	220
C₁₃H₇OBr			
2-Bromo-9-fluorenone (12.9 g.)	2- <i>p</i> -CH ₃ C ₆ H ₄ OC ₆ H ₄ MgI (15.5 g. C ₁₃ H ₁₁ IO)	2-Bromo-9- <i>o</i> -toloxyphenyl-9-fluorenol (14.0 g.)	71
C₁₃H₇O₂Br			
3-Bromoxanthone	C ₆ H ₅ MgBr (3 equiv.)	3-Bromo-9-phenylxanthhydrol	112
C₁₃H₇O₂Cl			
3-Chloroxanthone	C ₆ H ₅ MgBr (3 equiv.)	3-Chloro-9-phenylxanthhydrol (80%)	112

* 2-Methyl-3-ethyl-5-isopropenyl-2-cyclohexen-1-one.

[†] 1,3-Diethyl-2-methyl-5-isopropenyl-1,3-cyclohexadiene.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₈O			
9-Fluorenone (5.2 g.)	CH ₃ MgI (8.5 g. CH ₃ I)	9-Methyl-9-fluorenone (5.5 g., crude)	273,14,215
9-Fluorenone (20 g.)	(≡ CMgBr) ₂	1,4-Dibiphenylene-2-butyne-1,4-diol (6 g.)	29
9-Fluorenone	C ₂ H ₅ MgI	9-Ethyl-9-fluorenone (72.7%)	273
9-Fluorenone	2-Thienyl-MgI	9- α -Thienyl-9-fluorenone	200
9-Fluorenone (100 g.)	C ₆ H ₅ MgBr	9-Phenyl-9-fluorenone (140 g.)	10,173,272
9-Fluorenone	C ₆ H ₅ CH ₂ MgCl	9-Benzyl-9-fluorenone (76%)	273,173
9-Fluorenone (5.4 g.)	2-C ₆ H ₅ OC ₆ H ₄ MgI (8.9 g. C ₁₂ H ₉ IO)	9- α -Phenoxyphenyl-9-fluorenone (5.7 g.)	71
9-Fluorenone (9 g.)	2-C ₆ H ₅ CH ₂ C ₆ H ₄ MgBr (1.2 g. Mg)	9- α -Benzylphenyl-9-fluorenone (10.4 g.)	71
9-Fluorenone (1.35 g.)	9-Anthryl-MgBr (0.257 g. C ₁₄ H ₉ Br)	9-(9-Anthryl)-9-fluorenone (1.09 g., 30%)	12
9-Fluorenone	9-Phenanthryl-MgBr	9-(9-Phenanthryl)-9-fluorenone (60%)	11
9-Fluorenone	(C ₆ H ₅) ₂ C≡CHMgBr	9-(β,β -Diphenylvinyl)-9-fluorenone	160
9-Fluorenone	2-[(C ₆ H ₅) ₂ CH]C ₆ H ₄ MgBr	9- α -Benzhydrylphenyl-9-fluorenone (51%)	171
9-Fluorenone (35 g.)	1-Phenyl-2-biphenylenevinyl-MgBr (70 g. C ₂₀ H ₁₃ Br)	9-(α -Phenyl- β -biphenylenevinyl)- 9-fluorenone (38.5 g.)	159
9-Fluorenone (2 g.)	(C ₆ H ₅) ₂ C=(C ₆ H ₅)CMgBr (5 g. C ₂₀ H ₁₅ Br)	9-(α,β,β -Triphenylvinyl)-9-fluorenone	325
C₁₃H₈OS			
Thioxanthone	CH ₃ MgI	Product isolated as double salt; 9-Methyl- thioxanthylum chloride-mercuric chloride	82
Thioxanthone	C ₆ H ₅ MgBr	9-Phenyl-9-thioxanthone	53
Thioxanthone	C ₆ H ₅ CH ₂ MgCl (2 equiv.)	9-Benzyl-9-thioxanthone; 9-Benzylidenethioxanthone	82
C₁₃H₈O₂			
Xanthone	CH ₃ MgI	9-Methyl-9-xanthone	82
Xanthone	2-Thienyl-MgI	9- α -Thienyl-9-xanthone	200
Xanthone	4-BrC ₆ H ₄ MgBr	9- <i>p</i> -Bromophenyl-9-xanthone (50-60%)	112,177

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₈O₂ (cont.)			
Xanthone	4-ClC ₆ H ₄ MgI	9- <i>p</i> -Chlorophenyl-9-xanthanol	112,177
Xanthone	C ₆ H ₅ MgBr	9-Phenyl-9-xanthanol (93%)	53,112,173, 270
Xanthone (5.0 g.)	C ₆ H ₅ MgBr (15.0 g. C ₆ H ₅ Br)	9,9-Diphenylxanthene (0.5 g.)	252
Xanthone	C ₆ H ₅ CH ₂ MgCl	9-Benzyl-9-xanthanol; 9-benzylidene-xanthene	82
Xanthone	2-CH ₃ C ₆ H ₄ MgBr	9- <i>o</i> -Tolyl-9-xanthanol; unidentified byproduct	83,41
Xanthone	2-CH ₃ C ₆ H ₄ MgBr	9,9-Di- <i>o</i> -tolylxanthene	252
Xanthone	4-CH ₃ C ₆ H ₄ MgBr	9- <i>p</i> -Tolyl-9-xanthanol (70%)	173,112
Xanthone	4-CH ₃ OC ₆ H ₄ MgBr	9-Anisyl-9-xanthanol (72%)	173
Xanthone	C ₆ H ₅ CH=CHMgBr (+ HClO ₄)	9-Styryl-9-xanthanyl perchlorate (56%)	321
Xanthone	C ₆ H ₅ CH=CHMgBr	9-Styryl-9-xanthanol (isolated as corresponding chloride, 60%)	321
Xanthone	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ MgBr	9-(α -Ethoxy- <i>o</i> -tolyl)-9-xanthanol	41
Xanthone	1-C ₁₀ H ₇ MgBr	9- α -Naphthyl-9-xanthanol (76%)	173
Xanthone (4.9 g.)	2-C ₆ H ₅ C ₆ H ₄ MgI (7.0 g. C ₁₂ H ₉ I)	9- <i>o</i> -Biphenyl-9-xanthanol (4.3 g.)	71
Xanthone (4.9 g.)	2-C ₆ H ₅ OC ₆ H ₄ MgI (7.4 g. C ₁₂ H ₉ IO)	9- <i>o</i> -Phenoxyphenyl-9-xanthanol (6.3 g.)	71
Xanthone (4.9 g.)	2-C ₆ H ₅ CH ₂ C ₆ H ₄ MgBr (6.2 g. C ₁₃ H ₁₁ Br)	9- <i>o</i> -Benzylphenyl-9-xanthanol (6.9 g.)	71
Xanthone	(C ₆ H ₅) ₂ C=CHMgBr	9-(β,β -Diphenylvinyl)-9-xanthanol	320
Xanthone	2-[(C ₆ H ₅) ₂ CH]C ₆ H ₄ MgBr	9- <i>o</i> -Benzhydrylphenyl-9-xanthanol	71
C₁₃H₈O₄			
Euxanthone* (3 g.)	CH ₃ MgI (14 g. CH ₃ I)	1,7,9-Trihydroxy-9-methylxanthene	317
Euxanthone* (4 g.)	C ₆ H ₅ MgBr (20 g. C ₆ H ₅ Br)	1,7,9-Trihydroxy-9-phenylxanthene (4 g.)	317
1,8-Dihydroxyxanthone (3 g.)	C ₆ H ₅ MgBr (10 g. C ₆ H ₅ Br)	1,8,9-Trihydroxy-9-phenylxanthene	16

* 1,7-Dihydroxyxanthone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₉ON			
9(10 <i>H</i>)-Acridone (18.0 g., 0.092 mole)	CH ₃ MgI* (0.3 mole)	9-Methylacridine (6.0 g., 44%); 9,9-dimethylacridan (2.5 g., 17%); recovered ketone (4.0 g.)	348
9(10 <i>H</i>)-Acridone (13 g. 0.067 mole)	<i>n</i> -C ₄ H ₉ MgBr (0.4 mole)	9,9-Di- <i>n</i> -butylacridan (4 g., 24%)	348
9(10 <i>H</i>)-Acridone (9.8 g.)	C ₆ H ₅ MgBr (2.5 equiv.)	Recovered ketone (7.2 g.); 9-phenyl-acridine (2.6 g., 19%)	178
C₁₃H₁₄O			
2,4,6-Trimethyl-1(2 <i>H</i>)-naphthalenone	<i>i</i> -C ₃ H ₇ MgBr	1-Isopropyl-2,4,6-trimethyl-1,2-dihydro-naphthol	85
C₁₃H₁₄O₂			
2- <i>p</i> -Toluylcyclopentanone	C ₂ H ₅ MgBr	2-(<i>α-p</i> -Tolylpropylidene)cyclopentanone; 1-ethyl-2- <i>p</i> -toluylcyclopentene	113
C₁₃H₁₆O			
7-Isopropyl- <i>α</i> -tetralone †	CH ₃ MgX	1-Methyl-7-isopropyl-1,2,3,4-tetrahydro-1-naphthol (<i>ca.</i> 70%)	20
4-Ethyl-7-methyl- <i>α</i> -tetralone ‡ (9 g.)	<i>i</i> -C ₃ H ₇ MgBr (8 ml. C ₃ H ₇ Br)	1-Isopropyl-4-ethyl-7-methyl-1,2,3,4-tetrahydro-1-naphthol (10 g., crude)	87
2,4,7-Trimethyl- <i>α</i> -tetralone § (15.0 g.)	<i>i</i> -C ₃ H ₇ MgBr (15.6 g. C ₃ H ₇ Br)	1-Isopropyl-2,4,7-trimethyl-1,2,3,4-tetrahydro-1-naphthol (yielding 13.0 g., 76% hydrocarbon)	86

* In Bu₂O solution.† 7-Isopropyl-3,4-dihydro-1(2*H*)-naphthalenone.‡ 4-Ethyl-7-methyl-3,4-dihydro-1(2*H*)-naphthalenone.§ 2,4,7-Trimethyl-3,4-dihydro-1(2*H*)-naphthalenone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₁₆O (<i>cont.</i>)			
2,5,6-Trimethyl- α -tetralone*	CH ₃ MgI	1,2,5,6-Tetramethyl-1,2,3,4-tetrahydro-1-naphthol	232
2,5,7-Trimethyl- α -tetralone [†]	CH ₃ MgI (10 equiv.)	1,2,5,7-Tetramethyl-1,2,3,4-tetrahydro-1-naphthol; dehydr'n product	232
3,4,5-Trimethyl- α -tetralone [‡]	CH ₃ MgI (2 equiv.)	1,3,4,5-Tetramethyl-1,2,3,4-tetrahydro-1-naphthol; dehydr'n product	232
4,5,7-Trimethyl- α -tetralone [§] (10 g.)	<i>i</i> -C ₃ H ₇ MgBr	1-Isopropyl-4,5,7-trimethyl-1,2,3,4-tetrahydro-1-naphthol (11 g., crude)	86,85
C₁₃H₂₀O			
Decahydro-1-benz[<i>e</i>]-inden-4(2 <i>H</i>)-one (4.5 g.)	CH ₃ MgI (8.0 g. CH ₃ I)	4-Methyldodecahydro-1-benz[<i>e</i>]inden-4-ol (4.0 g.)	223
C₁₄H₁₀O			
Anthrone [¶]	CH ₃ MgX (3 equiv.)	9-Methylantracene	254,69,174
Anthrone [¶]	C ₂ H ₅ MgBr	9-Ethyl-9,10-dihydro-9-anthrol	254,174
Anthrone [¶]	<i>n</i> -C ₄ H ₉ MgBr	9- <i>n</i> -Butylantracene (43%)	247
Anthrone [¶]	<i>i</i> -C ₅ H ₁₁ MgBr	9-Isoamyl-9,10-dihydro-9-anthrol	254,174
Anthrone [¶]	C ₆ H ₅ MgBr	9-Phenyl-9,10-dihydro-9-anthrol	254
Anthrone [¶]	C ₆ H ₅ MgBr (3 equiv.)	9-Phenylantracene (50%)	93
Anthrone [¶]	(CH ₂) ₅ CHMgCl	9-Cyclohexylantracene	302
Anthrone [¶] (368 g., 2 moles)	<i>n</i> -C ₁₂ H ₂₅ MgBr (1668 g., 6.7 moles C ₁₂ H ₂₅ Br)	9- <i>n</i> -Dodecylantracene (375 g., 49.5%)	247

* 2,5,6-Trimethyl-3,4-dihydro-1(2*H*)-naphthalenone.[†] 2,5,7-Trimethyl-3,4-dihydro-1(2*H*)-naphthalenone.[‡] 3,4,5-Trimethyl-3,4-dihydro-1(2*H*)-naphthalenone.[§] 4,5,7-Trimethyl-3,4-dihydro-1(2*H*)-naphthalenone.[¶] 9(10*H*)-Anthracenone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₀O₃			
2-Methoxyxanthone	C ₆ H ₅ MgBr	2-Methoxy-9-phenyl-9-xanthenol	16
2-Methoxyxanthone	C ₆ H ₅ MgBr	Product isolated as double salt; 2-methoxy-9-phenylxanthylium chloride-ferric chloride	83
3-Methoxyxanthone	C ₆ H ₅ MgBr	Product isolated as isomer of double salt described above	83
3-Methoxyxanthone	C ₆ H ₅ MgBr	3-Methoxy-9-phenyl-9-xanthenol	16
4-Methoxyxanthone	C ₆ H ₅ MgBr	4-Methoxy-9-phenyl-9-xanthenol	16
C₁₄H₁₀O₄			
1-Hydroxy-7-methoxyxanthone	C ₆ H ₅ MgBr	9-(1-Hydroxy-7-methoxy-9-phenyl-xanthenyl)ether	317
1-Methoxy-7-hydroxyxanthone	C ₆ H ₅ MgBr	1-Methoxy-7,9-dihydroxy-9-phenylxanthene	318
C₁₄H₁₂O			
3,4-Dihydro-1(2 <i>H</i>)-phenanthrone (4 g.)	CH ₃ MgI (3 g. CH ₃ I)	C ₁₅ H ₁₄ (dehydration products of 1-methyl-1,2,3,4-tetrahydro-1-phenanthrol) (4 g.)	128
2,3-Dihydro-4(1 <i>H</i>)-phenanthrone	CH ₃ MgI	4-Methyl-1,2,3,4-tetrahydro-4-phenanthrol	128
2,3-Dihydro-4(1 <i>H</i>)-phenanthrone	C ₆ H ₅ MgBr	1,2,3,4-Tetrahydro-4-phenanthrol	75
2,3-Dihydro-4(1 <i>H</i>)-phenanthrone (6.5 g.)	(CH ₂) ₅ CHMgCl (5.9 g. C ₇ H ₇ Cl)	1,2,3,4-Tetrahydro-4-phenanthrol (2.2 g.)	75
2,3-Dihydro-4(1 <i>H</i>)-phenanthrone	C ₆ H ₅ (CH ₂) ₂ MgBr	After dehydr'n, 4-phenethyl-1,2-dihydrophenanthrene	25
C₁₄H₁₆O			
2-Methyl-2-carbomethoxy-6-methoxy- α -tetralone* (10.3 g.)	C ₂ H ₅ MgBr (0.00125 mole)	1-Ethyl-2-methyl-2-carbomethoxy-6-methoxy-1,2,3,4-tetrahydro-1-naphthol (9.8 g., 87%)	137

* 2-Methyl-2-carbomethoxy-6-methoxy-3,4-dihydro-1(2*H*)-naphthalenone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₆O (<i>cont.</i>)			
2-Methyl-2-carbomethoxy-7-methoxy- α -tetralone* (10.3 g.)	C ₂ H ₅ MgBr (0.00125 mole)	1-Ethyl-2-methyl-2-carbomethoxy-7-methoxy-1,2,3,4-tetrahydro-1-naphthol (9.5 g., 82%)	137
3-Phenyl-5,5-dimethyl-2-cyclohexen-1-one (20 g., 0.1 mole)	C ₆ H ₅ MgBr (0.5 mole C ₆ H ₅ Br)	1,3-Diphenyl-5,5-dimethyl-1,3-cyclohexadiene (14 g., 54%)	307
C₁₄H₁₆O₂			
2- <i>p</i> -Xyloylcyclopentanone	C ₂ H ₅ MgBr	1-Ethyl-2- <i>p</i> -xyloylcyclopentene	113
C₁₄H₁₈O			
2,4,6,7-Tetramethyl- α -tetralone †	<i>i</i> -C ₃ H ₇ MgCl	1-Isopropyl-2,4,6,7-tetramethyl-1-tetralol	58
3,4,5,7-Tetramethyl- α -tetralone ‡	CH ₃ MgI (excess)	1,3,4,5,7-Pentamethyl-3,4-dihydro-naphthalene	232
3,4,5,8-Tetramethyl- α -tetralone §	CH ₃ MgI (excess)	1,3,4,5,8-Pentamethyl-3,4-dihydro-naphthalene	232
3,4,6,7-Tetramethyl- α -tetralone ¶	<i>i</i> -C ₃ H ₇ MgCl	1-Isopropyl-3,4,6,7-tetramethyl-1-tetralol	58
C₁₄H₂₀O₆			
2,4-Diethyl-2,4-dicarbethoxy-1,3-cyclobutanedione (25 g.)	C ₆ H ₅ MgBr (1 equiv.)	Recovered ketone; C ₂ H ₅ (H ₅ C ₂ O ₂ C)C=CO; † 1,3-diphenyl-2,4-diethyl-2,4-dicarbethoxy-1,3-cyclobutanediol (15 g., crude); C ₂ H ₅ (C ₆ H ₅ CO)CHCO ₂ C ₂ H ₅ (15 g., crude)	138

* 2-Methyl-2-carbomethoxy-7-methoxy-3,4-dihydro-1(2*H*)-naphthalenone.

† 2,4,6,7-Tetramethyl-3,4-dihydro-1(2*H*)-naphthalenone.

‡ 3,4,5,7-Tetramethyl-3,4-dihydro-1(2*H*)-naphthalenone.

§ 3,4,5,8-Tetramethyl-3,4-dihydro-1(2*H*)-naphthalenone.

¶ 3,4,6,7-Tetramethyl-3,4-dihydro-1(2*H*)-naphthalenone.

† The cyclic diketone is a ketene dimer which, on distillation, is converted in part into the monomer.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₉OBr			
2-Bromo-3-phenylindenone (2.0 g.)	C ₆ H ₅ MgBr (2.4 g. C ₆ H ₅ Br)	1,3-Diphenyl-2-bromo-1-indenol (isolated as the acetate)	300
C₁₅H₁₀O₃			
1-Methoxyxanthone	C ₆ H ₅ CH=CHMgBr (+ HClO ₄)	1-Methoxy-9-styryl-9-xanthenyl perchlorate	321
C₁₅H₁₂O			
3-Phenyl-1-indanone	H ₂ C=CH(CH ₂) ₃ MgBr	1-(4-Pentenyl)-3-phenyl-1-indanol	187
1-Oxo-4,5-methylene-1,2,3,4-tetrahydrophenanthrene* (0.5 g.)	CH ₃ MgI	1-Methyl-4,5-methylene-1,2,3,4-tetrahydrophenanthren-1-ol † (>0.45 g.) †	13
1-Oxo-4,5-methylene-1,2,3,4-tetrahydrophenanthrene*	C ₂ H ₅ MgBr	1-Ethyl-4,5-methylene-1,2,3,4-tetrahydrophenanthren-1-ol § (>77%) †	13
C₁₅H₁₂O₂			
2-Methoxyanthrone ¶ (9.4 g.)	4-CH ₃ OC ₆ H ₄ MgI (23.4 g. C ₇ H ₇ IO)	2-Methoxy-9-anisylantracene (5.2 g.)	42
10-Methoxyanthrone †	C ₆ H ₅ CH ₂ MgCl (3 equiv.)	Anthraquinone; 9,9'-dioxo-10,10'-dimethoxy-10,10'-bis-(9,10-dihydroanthracyl); 9-benzyl-10-methoxy-9,10-dihydro-9-anthrol	18
7-Ethoxy- <i>peri</i> -naphthindenone-9**	C ₆ H ₅ MgBr (2 equiv.)	3-Ethoxy-9-phenyl-9,9a-dihydrobenzo-naphthenone	163

* 3,3a-Dihydro-4-cyclopenta[*def*]phenanthren-1(2*H*)-one.

† 1-Methyl-1,2,3,3a-tetrahydro-4-cyclopenta[*def*]phenanthren-1-ol.

‡ The figure reported represents the yield of hydrocarbon after dehydration and dehydrogenation of the alcohol.

§ 1-Ethyl-1,2,3,3a-tetrahydro-4-cyclopenta[*def*]phenanthren-1-ol.

¶ 2-Methoxy-9(10*H*)-anthracenone.

‡ 10-Methoxy-9(10*H*)-anthracenone.

** 3-Ethoxybenzonaphthenone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₂O₂ (cont.)			
8,8-Dimethyl- <i>peri</i> -naphthindan- dione-7,9 (3.3 g.)*	C ₆ H ₅ MgBr (1 equiv.)	Recovered ketone (1.5 g.); 2,2-dimethyl- 3-hydroxy-3-phenyl-2,3-dihydro-1-benzo- naphthenone (1.3 g.)	107
8,8-Dimethyl- <i>peri</i> -naphthindan- dione-7,9*	C ₆ H ₅ MgBr (3 equiv.)	1,3-Diphenyl-2,2-dimethyl-2,3-dihydrobenzo- naphthene-1,3-diol †	107
8,8-Dimethyl- <i>peri</i> -naphthindan- dione-7,9*	C ₆ H ₅ MgBr (3 equiv.)	1,3-Diphenyl-2,2-dimethyl-2,3-dihydrobenzo- naphthene-1,3-diol (small am't); 2,2- dimethyl-3-hydroxy-3,9-diphenyl-2,3- dihydro-1-benzonaphthenone ‡	107
Flavanone § (10 g.)	C ₆ H ₅ MgBr (22 g. C ₆ H ₅ Br)	2,4-Diphenyl-4-chromanol (10 g.)	181
2,7-Dimethylxanthone (6.0 g.)	C ₆ H ₅ MgBr (10.0 g. C ₆ H ₅ Br)	2,7-Dimethyl-9-phenyl-9-xanthenol (6.2 g.)	221
C₁₅H₁₂O₄			
2,2-Dimethoxyxanthone	C ₆ H ₅ MgBr	2,2-Dimethoxy-9-phenyl-9-xanthenol	16
C₁₅H₁₄O			
5-Methyl-3,4-dihydro-1(2 <i>H</i>)- anthracenone	CH ₃ MgI	1,5-Dimethyl-1,2,3,4-tetrahydro-1- anthracenol ¶	131
9-Methyl-3,4-dihydro-1(2 <i>H</i>)- phenanthrene	CH ₃ MgI	1,9-Dimethyl-1,2,3,4-tetrahydro-1- phenanthrol (> 50%) ††	130

* 2,2-Dimethyl-1,3(2*H*)-benzonaphthenedione.† Addition of Grignard reagent solution to ice-cooled C₆H₆-ketone solution; three hours standing; four hours at room temperature.‡ Slow (two hours) addition of Grignard reagent solution to boiling C₆H₆-ketone solution.

§ 2-Phenylchromanone.

¶ Isolated, after dehydration and dehydrogenation, as 1,5-dimethylantracene.

†† The figure reported represents the yield of hydrocarbon after dehydration and dehydrogenation of the alcohol.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₆O			
2-Cyclopentadecen-1-one (11.1 g.) + CuCl ₂ (50 mg.)	CH ₃ MgBr (1.5 g. Mg)	Muscone* (3.0 g.); 1-methyl-2-cyclopenta- decen-1-ol (5.2 g.)	332
3,5-Dimethyl-6-benzylidene-2- cyclohexen-1-one	C ₆ H ₅ MgBr ("large excess")	1-Phenyl-3,5-dimethyl-6-(α -hydroxybenzyl)- 2-cyclohexen-1-ol	164
C₁₅H₁₆O₂			
Furfurylidenecarvone † (10.0 g.)	C ₂ H ₅ MgBr (15.5 g. C ₂ H ₅ Br)	2-Methyl-3-ethyl-5-isopropenyl-6-fur- furylidenecyclohexanone (26.5%)	192
Furfurylidenecarvone † (10 g.)	<i>n</i> -C ₃ H ₇ MgBr (17 g. C ₃ H ₇ Br)	2-Methyl-3- <i>n</i> -propyl-5-isopropenyl-6- furfurylidenecyclohexanone (16.8%)	192
Furfurylidenecarvone † (10 g.)	<i>i</i> -C ₄ H ₉ MgCl (13 g. C ₄ H ₉ Cl)	2-Methyl-3-isobutyl-5-isopropenyl-6- furfurylidenecyclohexanone (24%)	192
Furfurylidenecarvone † (10 g.)	C ₆ H ₅ MgBr (21 g. C ₆ H ₅ Br)	2-Methyl-3-phenyl-5-isopropenyl-6- furfurylidenecyclohexanone (22%)	192
Furfurylidenecarvone † (8 g.)	C ₆ H ₅ CH ₂ MgCl (14 g. C ₇ H ₇ Cl)	2-Methyl-3-benzyl-5-isopropenyl-6- furfurylidenecyclohexanone (18%)	192
C₁₅H₁₈O₂			
2-Furfurylidenepulegone † (15 g.)	C ₂ H ₅ MgBr (23 g. C ₂ H ₅ Br)	2-Furfurylidene-8-ethyl- <i>p</i> -menthone § (6 g.)	191
2-Furfurylidenepulegone † (20 g.)	<i>n</i> -C ₃ H ₇ MgBr (34 g. C ₃ H ₇ Br)	2-Furfurylidene-8- <i>n</i> -propylmenthone (5 g.)	191
2-Furfurylidenepulegone † (15 g.)	<i>i</i> -C ₄ H ₉ MgCl (20 g. C ₄ H ₉ Cl)	2-Furfurylidene-8- <i>i</i> -butylmenthone (6 g.)	191
2-Furfurylidenepulegone † (20 g.)	C ₆ H ₅ MgBr (44 g. C ₆ H ₅ Br)	2-Furfurylidene-8-phenylmenthone (11 g.)	191
2-Furfurylidenepulegone † (20.0 g.)	C ₆ H ₅ CH ₂ MgCl (36.0 g. C ₇ H ₇ Cl)	2-Furfurylidene-8-benzylmenthone (12.5 g.)	191

* 3-Methylcyclopentadecanone.

† 2-Methyl-5-isopropenyl-6-furfurylidene-2-cyclohexen-1-one.

‡ 2-Furfurylidene-3-methyl-6-isopropylidenecyclohexanone; 2-furfurylidene- $\Delta^{4(8)}$ -*p*-menthen-3-one.§ 2-Furfurylidene-3-methyl-6-*t*-amylcyclohexanone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₈O₂ (cont.)			
α -Furfurylidene camphor*	C ₆ H ₅ MgBr (sl. excess)	Phenyl- α -camphoryl- α -furylmethane	304,305
α -Furfurylidene camphor*	C ₆ H ₅ CH ₂ MgCl	Benzyl- α -camphoryl- α -furylmethane	304,305
α -Furfurylidene camphor*	4-CH ₃ C ₆ H ₄ MgBr	<i>p</i> -Tolyl- α -camphoryl- α -furylmethane	304,305
α -Furfurylidene camphor*	4-CH ₃ OC ₆ H ₄ MgBr	Anisyl- α -camphoryl- α -furylmethane	304,305
C₁₅H₁₈O₃			
2-(α -Carboxyphenethyl)cyclohexanone (18 g.)	CH ₃ MgI (26 g. CH ₃ I)	1-Methyl-2-(α -carboxyphenethyl)cyclohexanol (15 g.)	114
C₁₅H₂₀O			
2,5-Dimethyl-8-isopropyl- α -tetralone (10 g.)	CH ₃ MgI (10 g. CH ₃ I)	After dehydr'n, 1,2,5-Trimethyl-8-isopropyl-3,4-dihydronaphthalene (9 g., 90%)	85,86
C₁₅H₂₀O₂			
2-Furfurylidene menthone †	CH ₃ MgX	2-[α -(α -Furyl)ethyl]menthone †	43
2-Furfurylidene menthone †	C ₂ H ₅ MgX	2-[α -(α -Furyl)propyl]menthone	43
2-Furfurylidene menthone †	<i>n</i> -C ₃ H ₇ MgX	2-[α -(α -Furyl)butyl]menthone	43
2-Furfurylidene menthone †	<i>i</i> -C ₃ H ₇ MgX	2-[α -(α -Furyl)isobutyl]menthone	43
2-Furfurylidene menthone †	<i>n</i> -C ₄ H ₉ MgX	2-[α -(α -Furyl)amyl]menthone	43
2-Furfurylidene menthone †	<i>i</i> -C ₄ H ₉ MgX	2-[α -(α -Furyl)isoamyl]menthone	43
2-Furfurylidene menthone †	<i>i</i> -C ₅ H ₁₁ MgX	2-[α -(α -Furyl)isohexyl]menthone	43
2-Furfurylidene menthone †	C ₆ H ₅ MgX	2-(Phenyl- α -furylmethyl)menthone	43

* 1,7,7-Trimethyl-3-furfurylidenebicyclo[2.2.1]heptan-2-one.

† 2-Furfurylidene-3-methyl-6-isopropylcyclohexanone.

‡ 2-[α -(α -Furyl)ethyl]-3-methyl-6-isopropylcyclohexanone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₂₀O₅ 2-Carbethoxy-2-carbethoxymethyl- cyclohexanone	C ₆ H ₅ MgBr	1-Phenyl-2-carbethoxy-2-carboxymethyl- cyclohexanol lactone	62
C₁₅H₂₆O 1,4a-Dimethyl-7- <i>n</i> -propyl-2- decalone	CH ₃ MgI	1,3,4a-Trimethyl-7- <i>n</i> -propyl-2-decalol	48
Tetrahydro- α -cyperone*	CH ₃ MgI	1,3,4a-Trimethyl-7-isopropyl-2-decalol + dehydr'n product	47
C₁₆H₈O₂S₂ Thioindigo	RMgBr [†]	Thioindigo white (?)	24
C₁₆H₁₀O₂ 2-Benzylidene-1,3-indandione	C ₆ H ₅ MgBr	10-Phenyl-9-bindenone [‡]	164
C₁₆H₁₀O₂N₂ Indigotin [§]	RMgBr [¶]	Reaction in 1:1 molecular ratio	243
C₁₆H₁₂O 2-Methyl-3-phenyl-1-indone	CH ₃ MgI (2 equiv.)	1,2-Dimethyl-3-phenyl-1-indenol (87%)	257
2-Methyl-3-phenyl-1-indone (11.0 g.)	C ₆ H ₅ CH ₂ MgCl (17.3 g. C ₇ H ₇ Cl)	1-Benzyl-2-methyl-3-phenyl-1-indenol (16.0 g., crude)	34

* 1,4a-Dimethyl-7-isopropyl-2-decalone.

[†]R = CH₃, C₂H₅, C₆H₅.[‡]10-Phenylindeno[1.2- α]inden-9(10*H*)-one.[§] $\Delta^2(2')$ -Bipseudoindoxyl.[¶]R = CH₃, C₂H₅, *i*-C₄H₉, *i*-C₅H₁₁, C₆H₅, C₆H₅CH₂, 4-CH₃C₆H₄.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₁₂O₃			
10-Acetoxyanthrone*	CH ₃ MgBr	9,10-Dimethylantracene (58.0%); anthraquinone [†] (40.5%) [‡]	103
10-Acetoxyanthrone*	CH ₃ MgBr	9,10-Dimethyl-9,10-dihydro-9-anthrol (18.5%); anthraquinone [†] (38.0%) [§]	103
C₁₆H₁₄O			
2-Methyl-3-phenyl-1-indanone	CH ₃ MgI (2 equiv.)	1,2-Dimethyl-3-phenyl-1-indanol (62%)	257
2-Phenyl- α -tetralone [¶]	C ₂ H ₅ MgI	1-Ethyl-2-phenyl-1-tetralol||	57
2-Phenyl- α -tetralone [¶]	<i>n</i> -C ₃ H ₇ MgX	1- <i>n</i> -Propyl-2-phenyl-1-tetralol	57
2-Phenyl- α -tetralone [¶]	<i>i</i> -C ₃ H ₇ MgX	1-Isopropyl-2-phenyl-1-tetralol	57
2-Phenyl- α -tetralone [¶]	C ₆ H ₅ MgBr	1,2-Diphenyl-1-tetralol	27
1,3-Dimethylantrone**	CH ₃ MgBr	1,3-Dimethylantraquinone (32%); 1,3-dimethylantracene; ^{††} 1,3,9,10-tetramethylantracene ^{††}	103
C₁₆H₁₆O			
2,8-Dimethyl-3,4-dihydro-1(2 <i>H</i>)-phenanthrene	CH ₃ MgI	1,2,8-Trimethyl-1,2,3,4-tetrahydro-1-phenanthrol (>60%) ^{††}	130

* 10-Acetoxy-9(10*H*)-anthracenone.[†] By atmospheric oxidation of anthrahydroquinone.[‡] Addition of Et₂O-ketone solution to stirred CH₃Br-free Grignard reagent solution; fifteen hours stirring at room temperature.[§] Addition of Et₂O-ketone solution to Mg-free Grignard reagent solution containing excess CH₃Br; fifteen hours stirring.[¶] 2-Phenyl-3,4-dihydro-1(2*H*)-naphthalenone.^{||} 1-Ethyl-2-phenyl-1,2,3,4-tetrahydro-1-naphthol.** 1,3-Dimethyl-9(10*H*)-anthracenone.^{††} By reduction of residual reddish oil.^{††} The figure recorded represents the overall yield of hydrocarbon after dehydration and dehydrogenation of the Grignard product.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₁₆O₂			
2-Methyl-7-methoxy-3,4-dihydro-1(2 <i>H</i>)-phenanthrone	H ₅ C ₂ O ₂ CCH ₂ CH ₂ Br + Mg	α -(1-Hydroxy-2-methyl-7-methoxy-1,2,3,4-tetrahydro-1-phenanthryl)propionic acid lactone	121
7-Methyl-9-methoxy-3,4-dihydro-1(2 <i>H</i>)-phenanthrone	CH ₃ MgI	1,7-Dimethyl-9-methoxy-1,2,3,4-tetrahydro-1-phenanthrol (50%)	237
C₁₆H₁₆O₃			
5,9-Dimethoxy-3,4-dihydro-1(2 <i>H</i>)-phenanthrone (4.6 g.)	CH ₃ MgI (1.8 ml. CH ₃ I)	1-Methyl-5,9-dimethoxy-3,4-dihydro-phenanthrene (3.4 g.); recovered ketone (<i>ca.</i> 0.7 g.)	132
C₁₆H₁₈O₃			
4a-Carbomethoxy-3,4,4a,9,10,10a-hexahydro-2(1 <i>H</i>)-phenanthrone (2.1 g.)	CH ₃ MgI (1.28 g. CH ₃ I)	After dehydration and dehydrogenation, 2-methylphenanthrene (0.7 g., crude)	133
C₁₇H₈OS₃			
2,3,6,5-Dithianaphtheno-1,4-thiapyrone (1 g.)	C ₆ H ₅ MgBr (9 g. C ₆ H ₅ Br)	4,4-Diphenyl-2,3,6,5-dithianaphtheno-1,4-thiapyran	252
2,3,6,5-Dithianaphtheno-1,4-thiapyrone (1.0 g.)	C ₆ H ₅ CH ₂ MgCl (5.5 g. C ₇ H ₇ Cl)	4,4-Dibenzyl-2,3,6,5-dithianaphtheno-1,4-thiapyran (0.3 g.); 4-hydroxy-4-benzyl-2,3,6,5-dithianaphtheno-1,4-thiapyran	252
2,3,6,5-Dithianaphtheno-1,4-thiapyrone (1 g.)	3-CH ₃ C ₆ H ₅ MgBr (9 g. C ₇ H ₇ Br)	4,4-Di- <i>m</i> -tolyl-2,3,6,5-dithianaphtheno-1,4-thiapyran	252
C₁₇H₁₀O			
Chrysofluorenone* (2.60 g.)	CH ₃ MgI (4.26 g. CH ₃ I)	11-Methyl-11-chrysofluorenol (2.30 g.)	14

* 11-Benzo[*a*]fluoren-11-one.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₁₀O (cont.)			
Chrysofluorenone*	C ₆ H ₅ MgBr	11-Phenyl-11-chrysofluorenenol (88%)	271
Benzanthrone † (20.0 g.)	CH ₃ MgI (35.5 g. CH ₃ I)	7-Methylene-5,6-dihydro-7-benz[de]anthracene (10.0 g.); 6-methyl-7-benz[de]anthracen-7-one	60
Benzanthrone †	C ₂ H ₅ MgI (3 equiv.)	6-Ethyl-7-benz[de]anthracen-7-one	60
Benzanthrone †	<i>n</i> -C ₃ H ₇ MgI	6- <i>n</i> -Propyl-7-benz[de]anthracen-7-one	61
Benzanthrone †	<i>n</i> -C ₄ H ₉ Br	3- <i>n</i> -Butyl-7-benz[de]anthracen-7-one †	207
Benzanthrone †	<i>n</i> -C ₄ H ₉ MgI	6- <i>n</i> -Butyl-7-benz[de]anthracen-7-one (60%)	61
Benzanthrone †	<i>t</i> -C ₄ H ₉ MgCl (3 equiv.)	7- <i>t</i> -Butyl-7-benz[de]anthracen-7-ol (20%)	4
Benzanthrone †	C ₆ H ₅ MgBr	1-Phenyl-7-benz[de]anthracen-7-one §	68
Benzanthrone †	C ₆ H ₅ MgBr	3-Phenyl-7-benz[de]anthracen-7-one †	207
Benzanthrone †	C ₆ H ₅ MgBr	6-Phenyl-7-benz[de]anthracen-7-one (75%)	61
Benzanthrone †	C ₆ H ₅ MgBr (3 equiv.)	6-Phenyl-7-benz[de]anthracen-7-one (42%)	4
Benzanthrone †	(CH ₂) ₅ CHMgCl	6-Cyclohexyl-7-benz[de]anthracen-7-one (15%)	4
Benzanthrone †	C ₆ H ₅ CH ₂ MgCl	6-Benzyl-7-benz[de]anthracen-7-one (22%)	4
Benzanthrone †	C ₆ H ₅ CH ₂ MgCl	6-Benzyl-7-benz[de]anthracen-7-one (?)	68
Benzanthrone †	<i>n</i> -C ₇ H ₁₅ MgBr	6- <i>n</i> -Heptyl-7-benz[de]anthracen-7-one (61%)	4
Benzanthrone †	1-C ₁₀ H ₇ MgBr	1- α -Naphthyl-7-benz[de]anthracen-7-one §	68

* 11-Benzo[*a*]fluoren-11-one.

† 7-Benz[de]anthracen-7-one.

‡ It is not specified in the available abstract whether the 3 position of the *Chemical Abstracts* and "Ring Index" system or the 3-*Bz* position of the system of numbering employed by Clar (68) (*i.e.*, the 1 position) is intended. In either case, however, the work of Charrier and Ghigi (61) and of Allen and Overbaugh (4) shows the constitution assigned to be erroneous. Undoubtedly, the 6 derivative was isolated.

§ In view of the work of Charrier and Ghigi (61) and of Allen and Overbaugh (4) there can be no doubt that the constitution here assigned is erroneous, and that the product isolated was the 6-phenyl derivative.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₁₂O₂			
Bis-1-indanone-3,3-spiran (2.48 g.)	C ₆ H ₅ MgBr (3.14 g. C ₆ H ₅ Br)	1,1'-Diphenylbis-1-indanol-3,3-spiran (75%); corresponding anhydride (0.3 g.)	180
Bis-1-indanone-3,3-spiran (2.48 g.)	C ₆ H ₅ CH ₂ MgCl (2.53 g. C ₇ H ₇ Cl)	1,1'-Dibenzylbis-1-indanol-3,3-spiran (I) (2.1 g.); 1-benzyl-1-indanol-1'-indanone- 3,3-spiran (II) (0.9 g.); dehydration product of I (0.4 g.)	180
1,2-Cyclopenteno-9,10- phenanthraquinone (505 mg.)	CH ₃ MgI (6 ml. CH ₃ I)	After dehydr'n, 9,10-dimethyl-1,2-cyclo- pentenophenanthrene (31.7 mg.)	55
C₁₇H₁₄O₂			
2-Methyl-2-benzoyl-1-indanone (4.0 g.)	C ₆ H ₅ MgBr (3 equiv.)	(1-Hydroxy-1-phenyl-2-methyl-2- indanyl)diphenylmethanol (>3.9 g.); (C ₆ H ₅) ₃ COH (1.3 g.); 2-methyl-1-indanone	109
C₁₇H₁₄O₃			
2-Methyl-10-acetoxyanthrone *	CH ₃ MgBr	2,9,10-Trimethylantracene (28%); 2-methylantraquinone [†] (27%)	103
C₁₇H₁₅O₃			
2-Methyl-2-carbomethoxy-7- methoxybenz[e]indan-3-one (2.0 g.)	C ₂ H ₅ MgBr (0.8 g. C ₂ H ₅ Br)	2-Methyl-2-carbomethoxy-7-methoxy- benz[e]indan-3-ol (250 mg.); recovered ketone (0.8 g.)	38
C₁₇H₁₆O			
1,2-Dihydro-1,2-cyclopenteno- phenanthren-4(3 <i>H</i>)-one (1.45 g.)	CH ₃ MgI	4-Methyl-1,2,3,4-tetrahydro-1,2-cyclo- pentenophenanthren-4-ol (yielding 124.5 mg. 4-methyl-1,2-cyclopenteno- phenanthrene)	55

* 2-Methyl-10-acetoxy-9(10*H*)-anthracenone.[†] By atmospheric oxidation of 2-methylantrahydroquinone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₁₆O₂			
2,2-Dimethyl-3-hydroxy-3-phenyl-1-indanone (2.6 g.)	C ₆ H ₅ MgBr (1 equiv.)	Recovered ketone (70%); no isolable product	108
1,4-Dimethyl-10-methoxyanthrone*	CH ₃ MgI (3 equiv.)	1,4,9-Trimethyl-10-methoxy-9-anthrol	18
1,4-Dimethyl-10-methoxyanthrone*	C ₆ H ₅ MgBr	1,4-Dimethyl-9-phenyl-10-methoxy-9-anthrol	18
C₁₇H₁₈O			
Benzylidenecarvone † (15 g.)	C ₂ H ₅ MgBr (22 g. C ₂ H ₅ Br)	2-Methyl-3-ethyl-5-isopropenyl-6-benzylidenecyclohexanone (35.5%)	192
Benzylidenecarvone † (10 g.)	<i>n</i> -C ₃ H ₇ MgBr (16 g. C ₃ H ₇ Br)	2-Methyl-3- <i>n</i> -propyl-5-isopropenyl-6-benzylidenecyclohexanone (3 g.)	192
Benzylidenecarvone † (15 g.)	<i>i</i> -C ₄ H ₉ MgCl (19 g. C ₄ H ₉ Cl)	2-Methyl-3-isobutyl-5-isopropenyl-6-benzylidenecyclohexanone (48.5%)	192
Benzylidenecarvone † (18 g.)	C ₆ H ₅ MgBr (39 g. C ₆ H ₅ Br)	2-Methyl-3-phenyl-5-isopropenyl-6-benzylidenecyclohexanone (33.5%)	192
Benzylidenecarvone † (10 g.)	C ₆ H ₅ CH ₂ MgCl (17 g. C ₇ H ₇ Cl)	2-Methyl-3-benzyl-5-isopropenyl-6-benzylidenecyclohexanone (36.0%)	192
C₁₇H₂₀O			
Benzylidenepulegone † (15 g.)	C ₂ H ₅ MgBr (22 g. C ₂ H ₅ Br)	2-Benzylidene-8-ethylmenthone (8 g.) §	191
Benzylidenepulegone † (30 g.)	<i>n</i> -C ₃ H ₇ MgBr (49 g.) C ₃ H ₇ Br)	2-Benzylidene-8- <i>n</i> -propylmenthone (12 g.)	191
Benzylidenepulegone † (20 g.)	<i>i</i> -C ₄ H ₉ MgCl (22 g. C ₄ H ₉ Cl)	2-Benzylidene-8-isobutylmenthone (7 g.)	191
Benzylidenepulegone † (20 g.)	C ₆ H ₅ MgBr (41 g. C ₆ H ₅ Br)	2-Benzylidene-8-phenylmenthone (12 g.)	191
Benzylidenepulegone † (20 g.)	C ₆ H ₅ CH ₂ MgCl (24 g. C ₇ H ₇ Cl)	2-Benzylidene-8-benzylmenthone (14.5 g.)	191

* 1,4-Dimethyl-10-methoxy-9(10*H*)-anthracenone.

† 2-Methyl-5-isopropenyl-6-benzylidene-2-cyclohexen-1-one.

‡ 2-Benzylidene-3-methyl-6-isopropylidenecyclohexanone.

§ 2-Benzylidene-3-methyl-6-*t*-amylcyclohexanone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₂₀O (<i>cont.</i>)			
α -Benzylidenecamphor*	CH ₃ MgX	1-Phenyl-1- α -camphorylethane	122
α -Benzylidenecamphor*	C ₂ H ₅ MgX	1-Phenyl-1- α -camphorylpropane	122
α -Benzylidenecamphor*	C ₆ H ₅ MgX	Diphenyl- α -camphorylmethane	122
C₁₇H₂₂O			
2-Methyl-3-benzyl-5-isopropenyl-cyclohexanone	CH ₃ MgI	1,2-Dimethyl-3-benzyl-5-isopropenyl-cyclohexanol	230
C₁₇H₂₈O			
1-(1,5-Dimethylhexyl)-6,7-dihydro-4(5 <i>H</i>)-indanone	CH ₃ MgI	1-(1,5-Dimethylhexyl)-7a-methyl-3a,6,7,7a-tetrahydro-4(5 <i>H</i>)-indanone	199
C₁₇H₂₈O₂			
4b,8,8-Trimethyl-10a-hydroxy-perhydrophenanthren-2-one (5 g.)	CH ₃ MgI (17 g. CH ₃ I)	2,4b,8,8-Tetramethyl-3,4,4a,4b,5,6,7,8,8a,9-decahydrophenanthrene	135,238
C₁₇H₃₂O			
2,6-Di- <i>n</i> -propyl-2,6-diisopropylcyclopentanone	CH ₃ MgI (5-6 equiv.)	No reaction	79
C₁₈H₁₂O			
5(12 <i>H</i>)-Naphthacenone	CH ₃ MgI	5-Methyl-5,12-dihydro-5-naphthacenol	69
1,2-Benz-9-anthrone [†]	CH ₃ MgCl	7-Methylbenz[<i>a</i>]anthracene (56%)	102
1,2-Benz-10-anthrone [‡]	<i>i</i> -C ₃ H ₇ MgCl	12-Isopropyl-7,12-dihydrobenz[<i>a</i>]anthracen-12-ol	73

* 1,7,7-Trimethyl-3-benzylidenebicyclo[2.2.1]heptan-2-one.

[†] Benz[*a*]anthracen-7(12*H*)-one.[‡] Benz[*a*]anthracen-12(7*H*)-one.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₈H₁₂O₂			
Benz[<i>a</i>]anthracene-5(6 <i>H</i>), 7(12 <i>H</i>)-dione (1.5 g.)	CH ₃ MgBr ("large excess")	5,7-Dimethylbenz[<i>a</i>]anthracene (810 mg., 54%)	213
C₁₈H₁₄O			
3,4-Dihydrobenz[<i>a</i>]anthracen-1(2 <i>H</i>)-one	CH ₃ MgI	1-Methyl-1,2,3,4,-Tetrahydrobenz[<i>a</i>]anthracen-1-ol	78
7,12-Dihydrobenz[<i>a</i>]anthracen-5(6 <i>H</i>)-one (700 mg.)	CH ₃ MgBr	5-Methyl-5,6,7,12-tetrahydrobenz[<i>a</i>]anthracen-5-ol (422 mg., 61.6%)	213
10,11-Dihydrobenz[<i>a</i>]anthracen-8(9 <i>H</i>)-one (13.8 g.)	C ₂ H ₅ MgBr (22 g. C ₂ H ₅ Br)	After Pd-charcoal treatment, 8-ethyl-10,11-dihydrobenz[<i>a</i>]anthracene (79%)	8
10,11-Dihydrobenz[<i>a</i>]anthracen-8(9 <i>H</i>)-one	H ₂ C=CHCH ₂ Br + Mg	8-Allyl-8,9,10,11-tetrahydrobenz[<i>a</i>]anthracen-8-ol (84%)	8
10,11-Dihydrobenz[<i>a</i>]anthracene-8(9 <i>H</i>)-one (5.0 g.)	<i>n</i> -C ₃ H ₇ MgBr (4.0 ml. C ₃ H ₇ Br)	8- <i>n</i> -Propyl-8,9,10,11-tetrahydrobenz[<i>a</i>]anthracen-8-ol (2.2 g.)	8
C₁₈H₁₄O₂			
11-Methoxy-15,16-dihydro-17-cyclopenta[<i>a</i>]phenanthren-17-one (1.0 g.)	C ₂ H ₅ MgBr (3.0 g. C ₂ H ₅ Br)	11-Methoxy-17-ethyl-15-cyclopenta[<i>a</i>]phenanthrene (0.6 g.)	223
C₁₈H₁₆O			
3- <i>m</i> -Biphenyl-2-cyclohexen-1-one (25.0 g.)	C ₆ H ₅ MgBr (25.0 g. C ₆ H ₅ Br)	2-Phenyl-4- <i>m</i> -biphenyl-1,3-cyclohexadiene (22.7 g., crude)	309
3- <i>m</i> -Biphenyl-2-cyclohexen-1-one	3-C ₆ H ₅ C ₆ H ₄ MgBr (30.3 g. C ₁₂ H ₉ Br)	2,4-Bis- <i>m</i> -biphenyl-1,3-cyclohexadiene (11.4 g., crude)	309
3- <i>p</i> -Biphenyl-2-cyclohexen-1-one (10.0 g., 0.04 mole)	C ₆ H ₅ MgBr (18.7 g. C ₆ H ₅ Br)	1- <i>p</i> -Biphenyl-3-phenyl-1,3-cyclohexadiene	

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₈H₁₆O (<i>cont.</i>)			
3- <i>p</i> -Biphenyl-2-cyclohexen-1-one (15.0 g.)	3-C ₆ H ₅ C ₆ H ₄ MgBr (25.0 g. C ₆ H ₅ Br)	2- <i>m</i> -Biphenyl-4- <i>p</i> -biphenyl-1,3-cyclohexadiene (9.6 g.)	309
3,5-Diphenyl-2-cyclohexen-1-one	C ₂ H ₅ MgBr (excess)	1,5-Diphenyl-3-ethylidenecyclohexene; 3-ethyl-3,5-diphenylcyclohexanone	164
3,5-Diphenyl-2-cyclohexen-1-one	C ₆ H ₅ MgBr (excess)	1,3,5-Triphenyl-1,3-cyclohexadiene	164
5,6,8,9-Tetrahydrobenz[<i>a</i>]anthracen-11(10 <i>H</i>)-one	CH ₃ MgCl	11-Methyl-5,6,8,9-tetrahydrobenz[<i>a</i>]anthracene (86%)	104
C₁₈H₁₆O₂			
2,3-Dimethyl-4-hydroxy-4-phenyl-1(4 <i>H</i>)-naphthalenone	C ₆ H ₅ MgBr (excess)	1,2-Diphenyl-2,3-dimethyl-1,2-dihydronaphthalene-1,4-diol	326
C₁₈H₁₈O₂			
2,2-Dimethyl-3-methoxy-3-phenyl-1-indanone	C ₆ H ₅ MgBr	1,3-Diphenyl-2,2-dimethyl-3-methoxy-1-indanol	108,300
C₁₈H₁₈O₃			
2-Anisyl-6-methoxy-3,4-dihydro-1(2 <i>H</i>)-naphthalenone	CH ₃ MgI	1-Methyl-2-anisyl-6-methoxy-3,4-dihydronaphthalene	194
C₁₈H₁₈O₄			
2-Methyl-2-carbomethoxy-7-methoxy-3,4-dihydrophenanthren-1(2 <i>H</i>)-one (8 parts)	C ₂ H ₅ MgBr (12 parts C ₂ H ₅ Br)	1-Ethyl-2-methyl-2-carbomethoxy-7-methoxy-1,2,3,4-tetrahydrophenanthren-1-ol	258,196
C₁₈H₂₀O₄			
2-Methyl-2-carbomethoxy-7-methoxy-3,4,9,10-tetrahydrophenanthren-1(2 <i>H</i>)-one	C ₂ H ₅ MgI (1 equiv.)	1-Ethylidene-2-methyl-2-carbomethoxy-1,2,3,4,9,10-hexahydrophenanthrene	136

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₈H₂₆O			
2,2,6,6-Tetraälylcyclohexanone (15 g.)	CH ₃ MgI (5 equiv.)	Recovered ketone (7 g.); "polymerization" products	79
C₁₈H₂₆O₃			
4b,8-Dimethyl-8-carbomethoxy-4,4a,4b,5,6,7,8,8a,9,10-decahydrophenanthren-2(3 <i>H</i>)-one (5.8 g.)	CH ₃ MgI (5.7 g. CH ₃ I)	2,4b,8-Trimethyl-8-carbomethoxy-2,3,4,4a,4b,5,6,7,8,8a,9,10-dodecahydrophenanthren-2-ol (3.0 g.)	126
C₁₈H₃₄O			
2,2,6,6-Tetra- <i>n</i> -propylcyclohexanone (13 g.)	CH ₃ MgI (5 equiv.)	1-Methylene-2,2,6,6-tetra- <i>n</i> -propylcyclohexane (11 g.)	79
10-Phenyl-9(10 <i>H</i>)-acridone (3.7 g.)	C ₆ H ₅ MgBr (6.0 ml. C ₆ H ₅ Br)	9,10-Diphenyl-9-acridanol (4.0 g.)	349
C₁₉H₁₄O			
Fuchsone*	CH ₃ MgI (3 equiv.)	<i>p</i> -HOC ₆ H ₄ (C ₆ H ₅) ₂ CCH ₃	150
C₁₉H₁₆O₂			
3-Methyl-11-methoxy-15,16-dihydro-17-cyclopenta[<i>a</i>]phenanthren-17-one (7 g.)	CH ₃ MgI	3,17-Dimethyl-11-methoxy-15-cyclopenta[<i>a</i>]phenanthrene (6 g.)	170
C₁₉H₂₀O₄			
2-Methyl-2-carbethoxy-7-methoxy-3,4-dihydrophenanthren-1(2 <i>H</i>)-one	C ₂ H ₅ MgBr	1-Ethyl-2-methyl-2-carbethoxy-7-methoxy-1,2,3,4-tetrahydrophenanthren-1-ol	258

* 4-Benzhydrylidene-2,5-cyclohexadiene-1-one.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₉H₂₁O₂N			
2-Piperidinomethyl-1-benzo- [f]chromanone (17.8 g., 0.06 mole)	CH ₃ MgI (17.0 g., 0.12 mole CH ₃ I)	1-Methyl-2-piperidinomethyl-1-benzo- [f]chromanol (yielding 4.7 g., 22.6% of the chromene hydrochloride)	9
2-Piperidinomethyl-1-benzo- [f]chromanone (29.5 g., 0.1 mole)	C ₂ H ₅ MgBr (54.5 g., 0.5 mole C ₂ H ₅ Br)	1-Ethyl-2-piperidinomethyl-1-benzo- [f]chromanol (44.5%)	9
C₂₀H₂₂O₄			
2-Ethyl-2-carbethoxy-7-methoxy- 3,4-dihydrophenanthren- 1(2H)-one	C ₂ H ₅ MgBr	1,2-Diethyl-2-carbethoxy-7-methoxy-1,2,3,4- tetrahydrophenanthren-1-ol	258,196
C₁₉H₁₆O			
2,2,6,6-Tetra- <i>n</i> -propyl-3-methyl- cyclohexanone (15 g.)	CH ₃ MgI (5 equiv.)	Recovered ketone; dehydr'n product (total recovery, 8 g.)	79
2,2,6,6-Tetra- <i>n</i> -propyl-4-methyl- cyclohexanone (15 g.)	CH ₃ MgI (5 equiv.)	Dehydr'n product (12 g.)	79
C₂₀H₁₃ON			
10-Phenyliminoanthrone (8.0 g., 0.028 mole)	C ₆ H ₅ MgBr (9.0 g. C ₆ H ₅ Br)	9-Phenyl-10-phenylimino-9,10-dihydro- 9-anthrol (8.7 g., 85%)	149
C₂₀H₁₄O			
Acebenzanthrone*	CH ₃ MgI	7-Methyl-4,5-dihydrobenz[k]acephe- nanthrylene (30%)	198
Acebenzanthrone*	C ₂ H ₅ MgBr	7-Ethyl-4,5-dihydrobenz[k]acephe- nanthrylene (28.6%)	198

* 4,5-Dihydrobenz[k]acephenanthrylen-7(12H)-one.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₀H₁₄O (<i>cont.</i>)			
Acebenzanthrone*	<i>n</i> -C ₃ H ₇ MgBr	7- <i>n</i> -Propyl-4,5-dihydrobenz[<i>k</i>]acephenanthrylene (25%)	198
Acebenzanthrone*	<i>n</i> -C ₄ H ₉ MgBr	7- <i>n</i> -Butyl-4,5-dihydrobenz[<i>k</i>]acephenanthrylene (20.7%)	198
10-Phenylanthrone [†]	(CH ₂) ₅ CHMgCl	9-Phenyl-10-cyclohexylanthracene	302
9,10-Dihydrobenzo[<i>a</i>]pyren-7(8 <i>H</i>)-one	CH ₃ MgI	7-Methyl-9,10-dihydrobenzo[<i>a</i>]pyrene	101
C₂₀H₁₄O₃			
10-Benzoxanthrone [‡]	CH ₃ MgCl	Benzoic acid (11%); anthraquinone [§] (25%); 9,10-dimethylanthracene (50%)	103
10-Benzoxanthrone [‡]	CH ₃ MgBr (2.75 equiv.)	Benzoic acid (13%); anthrahydroquinone monobenzoate (7.5%); 9,10-dimethylanthracene (9%); anthraquinone [§] (60%)	103
C₂₀H₂₄O			
17-Isopropyl-6,7,8,14,16,17-hexahydro-15-cyclopenta[<i>a</i>]phenanthren-11(9 <i>H</i>)-one (2.0 g.) + CuBr [¶] (0.1 g.)	CH ₃ MgI [¶] (1.0 g. CH ₃ I)	11-Methyl-17-isopropyl-6,7,8,14,16,17-hexahydro-15-cyclopenta[<i>a</i>]phenanthrene (1.4 g.)	333

* 4,5-Dihydrobenz[*k*]acephenanthrylen-7(12*H*)-one.

[†] 10-Phenylanthracen-9(10*H*)-one.

[‡] 10-Benzoxanthracen-9(10*H*)-one.

[§] By atmospheric oxidation of anthrahydroquinone.

[¶] "Repetition of the Grignard addition under varying conditions, using methylmagnesium bromide and cuprous chloride, gave essentially the same results."

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₁H₁₂O₂			
7-Dibenzo[<i>c,b</i>]xanthone	C ₆ H ₅ MgBr	7-Phenyl-7-dibenzo[<i>c,b</i>]xanthen-7-ol	67
C₂₁H₁₄O			
2,3-Diphenyl-1-indone	C ₆ H ₅ CH ₂ MgCl	1-Benzyl-2,3-diphenyl-1-indenol	34
2,3-Diphenyl-1-indone	4-CH ₃ C ₆ H ₄ MgBr	1- <i>p</i> -Tolyl-2,3-diphenyl-1-indenol	161
10-Benzalanthrone* (14 g.)	CH ₃ MgI (22 g. CH ₃ I)	9-Methyl-10-benzylidene-9,10-dihydro-9-anthrol (13 g., crude)	148
10-Benzalanthrone*	C ₆ H ₅ MgBr	Anthrafuchsone †	207
14-Dibenzo[<i>a,f</i>]xanthen-14-one (3 g.)	C ₆ H ₅ MgBr (14 g. C ₆ H ₅ Br)	14-Phenyl-14-dibenzo[<i>a,f</i>]xanthen-14-ol	88
14-Dibenzo[<i>a,i</i>]xanthen-14-one (3 g.)	C ₆ H ₅ MgBr (14 g. C ₆ H ₅ Br)	14-Phenyl-14-dibenzo[<i>a,i</i>]xanthen-14-ol	88
C₂₁H₁₆O			
2,3-Diphenyl-1-indanone (2.3 g.)	CH ₃ MgI (0.255 g. Mg)	1,2-Diphenyl-3-methylindene (1.6 g., 70%)	162
2,3-Diphenyl-1-indanone (1.4 g.)	C ₆ H ₅ CH ₂ MgCl (1.8 g. C ₇ H ₇ Cl)	1-Benzyl-2,3-diphenyl-1-indanol (0.8 g.)	31
2,3-Diphenyl-1-indanone (18 g.)	4-CH ₃ C ₆ H ₄ MgBr (2.4 g. C ₇ H ₇ Br)	1- <i>p</i> -Tolyl-2,3-diphenyl-1-indanol (9.4 g.)	161
C₂₁H₁₆O₂			
10-Methoxy-10-phenylanthrone	Furyl-MgBr	9-Furyl-10-methoxy-10-phenyl-9,10-dihydroanthrol	100
C₂₁H₂₀O			
2,6-Dibenzylidene-3-methylcyclohexanone	C ₆ H ₅ MgBr (excess)	2-Benzylidene-3-methyl-6-benzhydryl-cyclohexanone; 2-benzhydryl-3-methyl-6-benzylidenecyclohexanone	164

* 10-Benzylidene-9(10*H*)-anthracenone.† 10-Benzhydrylideneanthracen-9(10*H*)-one.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₁H₂₅OS			
3-Ethyl thio enol ether of Δ^4 -androstene-3,17-dione (2.9 g.)	HC \equiv CMgBr (15 g. C ₂ H ₅ MgBr)	3-Ethyl thio enol ether of 17-ethynyltestosterone	195
C₂₁H₂₆OS₂			
3-Ethylene mercaptol of Δ^4 -androstene-3,17-dione (2.9 g.)	CH ₃ MgBr (3.6 g.)	3-Ethylene mercaptol of 17-methyltestosterone	195
C₂₁H₃₀O₂			
Δ^4 -Androstene-3,17-dione 3-enol ethyl ether	CH ₃ MgX	17-Methyltestosterone	341
Δ^4 -Androstene-3,17-dione 3-enol ethyl ether	HC \equiv CMgBr	17-Ethynyltestosterone	341
Δ^4 -Androstene-3,17-dione 3-enol ethyl ether	C ₂ H ₅ MgX	17-Ethyltestosterone	341
C₂₁H₃₀O₃			
Δ^4 -Androstene-3,17-dione 3-glycol acetal	CH ₃ MgX	17-Methyltestosterone 3-glycol acetal	340
Δ^4 -Androstene-3,17-dione 3-glycol acetal	HC \equiv CMgBr	17-Ethynyltestosterone 3-glycol acetal	340
Δ^4 -Androstene-3,17-dione 3-glycol acetal	C ₂ H ₅ MgX	17-Ethyltestosterone 3-glycol acetal	340
<i>trans</i> -Dehydroandrosterone acetate (3.3 g.)	CH ₃ MgI (1.2 g. Mg)	Normal addition product, which was further treated without isolation	77
C₂₁H₃₂O₂			
Androstane-3,17-dione	CH ₃ MgX	17-Methylandrostan-3-on-17-ol	339
Androstane-3,17-dione	C ₂ H ₅ MgX	17-Ethylandrostan-3-on-17-ol	339

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₂H₁₄O			
6(13 <i>H</i>)-Pentacenone	CH ₃ MgI	6-Methyl-6,13-dihdropentacen-6-ol; C ₄₆ H ₃₂ , m.p. 420°	69
C₂₂H₁₆O			
2-Benzyl-3-phenyl-1-indone (3.2 g.)	C ₆ H ₅ MgBr (7.5 g. C ₆ H ₅ Br)	1,3-Diphenyl-2-benzyl-1-indenol (2.0 g.)	34
2-Phenyl-3-benzyl-1-indone	C ₆ H ₅ CH ₂ MgCl	1,3-Dibenzyl-2-phenyl-1-indenol	298
2-Phenyl-3- <i>p</i> -tolyl-1-indone (15.0 g.)	C ₆ H ₅ MgBr (2.2 g. Mg)	1,2-Diphenyl-3- <i>p</i> -tolyl-1-indenol (15.0 g.)	161
C₂₂H₁₆O₂			
2-Benzoyl-3-phenyl-1-indanone (2.5 g.)	C ₆ H ₅ MgBr (6.4 g. C ₆ H ₅ Br)	C ₂₈ H ₂₀ O, m.p. 145-146°	184
C₂₂H₁₈O			
2,2,3-Triphenylcyclobutanone	CH ₃ MgI	1-Methyl-2,2,3-triphenylcyclobutanol (87%)	261
2-Phenyl-3- <i>p</i> -tolyl-1-indanone	C ₆ H ₅ MgBr	1,2-Diphenyl-3- <i>p</i> -tolyl-1-indanol (55%)	161
6a,13,14,14a-Tetrahydropicen- 5(6 <i>H</i>)-one	CH ₃ MgBr (excess)	5-Methyl-5,6,6a,13,14,14a-hexahydropicen- 5-ol	210
6b,7,8,12b-Tetrahydropicen- 14(13 <i>H</i>)-one	CH ₃ MgBr (excess)	14-Methyl-6b,7,8,12b,13,14-hexahydro- picen-14-ol	210
C₂₂H₂₄O			
2,3-Diphenyl- α -tetralone*	C ₆ H ₅ MgBr	1,2,3-Triphenyl-1,2,3,4-tetrahydro-1- naphthol (70%, crude)	30
C₂₃H₁₄O			
3-Phenyl-7-benz[<i>de</i>]anthracen- 7-one	C ₂ H ₅ MgX	3-Phenyl-6-ethyl-7-benz[<i>de</i>]anthracen-7-one (35%)	5

* 2,3-Diphenyl-3,4-dihydro-1(2*H*)-naphthalenone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₃H₁₄O (<i>cont.</i>)			
3-Phenyl-7-benz[<i>de</i>]anthracen-7-one	<i>n</i> -C ₄ H ₉ MgX	3-Phenyl-6- <i>n</i> -butyl-7-benz[<i>de</i>]anthracen-7-one (53%)	5
3-Phenyl-7-benz[<i>de</i>]anthracen-7-one	<i>t</i> -C ₄ H ₉ MgCl	3-Phenyl-7- <i>t</i> -butyl-7-benz[<i>de</i>]anthracen-7-ol (10%)	5
3-Phenyl-7-benz[<i>de</i>]anthracen-7-one	C ₆ H ₅ MgBr	3,6-Diphenyl-7-benz[<i>de</i>]anthracen-7-one (45%)	5
3-Phenyl-7-benz[<i>de</i>]anthracen-7-one	(CH ₂) ₅ CHMgX	3-Phenyl-6-cyclohexyl-7-benz[<i>de</i>]anthracen-7-one (22%)	5
3-Phenyl-7-benz[<i>de</i>]anthracen-7-one	<i>n</i> -C ₆ H ₁₃ MgX	3-Phenyl-6- <i>n</i> -hexyl-7-benz[<i>de</i>]anthracen-7-one (47%)	5
3-Phenyl-7-benz[<i>de</i>]anthracen-7-one	C ₆ H ₅ CH ₂ MgCl	3-Phenyl-6-benzyl-7-benz[<i>de</i>]anthracen-7-one (19%)	5
3-Phenyl-7-benz[<i>de</i>]anthracen-7-one	C ₆ H ₅ CH=CHMgX	3-Phenyl-6-styryl-7-benz[<i>de</i>]anthracen-7-one (6%)	5
C₂₃H₁₆O			
Naphthofuchsone*	CH ₃ MgI	1-(4-HOC ₁₀ H ₆)(C ₆ H ₅) ₂ CCH ₃	150
C₂₃H₁₆O₂			
1,2,4-Triphenylcyclopentene-3,5-dione (16.2 g.)	C ₆ H ₅ MgBr (40.0 g. C ₆ H ₅ Br)	2,4,5-Triphenylcyclopentane-1,3-dione (8.7 g.); 1,2,3,4-tetraphenylcyclopenten-3-ol-5-one (0.8 g.)	357
C₂₃H₂₀O			
2,7-Diphenyl-4,5-benzocycloheptanone (1.4 g.)	CH ₃ MgI (1.8 g. CH ₃ I)	1-Methyl-2,7-diphenyl-4,5-benzocycloheptanol (1.2 g.)	265

* 4-Benzhydrylidene-1(4*H*)-naphthalenone.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₄H₂₀O			
2,3-Dimethyl-2,4-diphenyl-1(2 <i>H</i>)-naphthalenone	C ₆ H ₅ MgBr (excess)	1,2,4-Triphenyl-2,3-dimethyl-1,2-dihydro-1-naphthol	326
2,3-Dimethyl-4,4-diphenyl-1(4 <i>H</i>)-naphthalenone	C ₆ H ₅ MgBr	1,4,4-Triphenyl-2,3-dimethyl-1,4-dihydro-1-naphthol (90%)	326
C₂₅H₂₄O			
1,3-Diphenyl-9-fluorenone	C ₆ H ₅ MgBr	1,3,9-Triphenyl-9-fluorenol	165
C₂₆H₁₈O₂			
1-(9-Hydroxy-9-fluorenyl)-9-fluorenone	C ₆ H ₅ MgBr	1-(9-Hydroxy-9-fluorenyl)-9-phenyl-9-fluorenol	159
C₂₆H₁₈O			
10,10-Diphenylanthrone*	C ₆ H ₅ MgBr	9,10-10-Triphenyl-9-anthrol (<i>ca.</i> quant.)	123,173,19
10,10-Diphenylanthrone* (30.0 g.)	4-CH ₃ OC ₆ H ₄ MgI (35.4 g. C ₇ H ₇ IO)	9- <i>p</i> -Anisyl-10,10-diphenyl-9-anthrol (22.5 g.)	39
C₂₇H₁₈O			
Anthrafuchsone [†]	CH ₃ MgI	9-Methyl-10-benzhydrylidene-9,10-dihydro-9-anthrol	150
C₂₇H₂₆O			
2-Benzylidene-3-methyl-6-benzhydrylcyclohexanone	C ₆ H ₅ MgBr	2,6-Dibenzhydryl-3-methylcyclohexanone	164
2-Benzhydryl-3-methyl-6-benzylidenecyclohexanone	C ₆ H ₅ MgBr	2,6-Dibenzhydryl-3-methylcyclohexanone	164

* 10,10-Diphenylanthracen-9(10*H*)-one.[†] 10-Benzhydrylideneanthrone; 10-benzhydrylideneanthracen-9(10*H*)-one.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₇H₄₄O			
Cholestenone (5.0 g.)	C ₆ H ₅ MgBr (6.2 g. C ₆ H ₅ Br)	3-Phenyl-4-cholesten-3-ol (80%)	28,274
Cholestenone	1-C ₁₀ H ₇ MgBr (3 equiv.)	After dehydr'n, a 3- α -naphthyl-cholestadiene	274
C₂₇H₄₆O			
3-Cholestanone	CH ₃ MgI	3-Methyl-3-cholestanol	170
3-Cholestanone	CH ₃ MgI (excess)	3-Methylcholestene	170
C₂₇H₄₆O₂			
6-Ketocholestanol	CH ₃ MgI	6(α)-Methylcholestane-3(β),6(β)-diol	364
6-Ketocholestanol	C ₆ H ₅ MgBr	6-Phenyl-3,6-cholestanediol	65
C₂₈H₁₆O₂			
Dianthraquinone *	2-ClC ₆ H ₄ MgX	9,9'-Di-o-chlorophenyl- $\Delta^{10(9H),10'(9'H)}$ -bi-9-anthrol †	329
Dianthraquinone * (4.0 g.)	C ₆ H ₅ MgBr (7.2 g. C ₆ H ₅ Br)	9,9'-Diphenyl- $\Delta^{10(9H),10'(9'H)}$ -bi-9-anthrol	329
Dianthraquinone *	C ₆ H ₅ CH ₂ MgX	9,9'-Dibenzyl- $\Delta^{10(9H),10'(9'H)}$ -bi-9-anthrol	329
Dianthraquinone *	1-C ₁₀ H ₇ MgX	9,9'-Di- α -naphthyl- $\Delta^{10(9H),10'(9'H)}$ -bi-9-anthrol	329
C₂₈H₂₂O₃			
10,10-Dianysylanthrone † (16.0 g.)	4-CH ₃ OC ₆ H ₄ MgI (18.9 g. C ₇ H ₇ IO)	9,10,10-Trianisyl-9,10-dihydro-9-anthrol (15.0 g.)	39

* $\Delta^{10,10'}$ -Bianthrone; 10,10'-Dioxo- $\Delta^{9,9'}$ -9,9',10,10'-Tetrahydro-9,9'-bianthracyl.

† 10,10'-Dihydroxy-10,10'-di-o-chlorophenyl- $\Delta^{10,10'}$ -9,9',10,10'-tetrahydro-9,9'-bianthracyl.

‡ 10,10-Dianysylanthracen-9(10H)-one.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₉H₁₈O			
1,3-Diphenyl-2-cyclopenta- [<i>l</i>]phenanthren-2-one	C ₂ H ₅ MgBr	1,3-Diphenyl-2-ethyl-2-cyclopenta[<i>l</i>]phe- nanthren-2-ol (53-75%)*	1
1,3-Diphenyl-2-cyclopenta- [<i>l</i>]phenanthren-2-one	<i>n</i> -C ₄ H ₉ MgBr	1,3-Diphenyl-2- <i>n</i> -butyl-2-cyclopenta[<i>l</i>]phe- nanthren-2-ol (53-75%)*	1
1,3-Diphenyl-2-cyclopenta- [<i>l</i>]phenanthren-2-one	C ₆ H ₅ MgBr	1,2,3-Triphenyl-2-cyclopenta[<i>l</i>]phenanthren- 2-ol (53-75%)*	1
1,3-Diphenyl-2-cyclopenta- [<i>l</i>]phenanthren-2-one	C ₆ H ₅ CH ₂ MgCl	1,3-Diphenyl-2-benzyl-2-cyclopenta[<i>l</i>]phe- nanthren-2-ol (53-75%)*	1
C₂₉H₁₈OBr₂			
2,5-Diphenyl-3,4-di- <i>p</i> -bromo- phenyl-2,4-cyclopentadien- 1-one (5.4 g.)	C ₆ H ₅ MgBr	1,2,5-Triphenyl-3,4-di- <i>p</i> -bromophenyl-2,4- cyclopentadien-1-ol (4.1 g.)	6
C₂₉H₂₂O			
1,1,4-Triphenyl-3-methyl- naphthalen-2(1 <i>H</i>)-one	CH ₃ MgI	1,1,4-Triphenyl-2-methylene-3-methyl- 1,2-dihydronaphthalene	326
C₂₉H₂₄O₄			
2-Methoxy-10,10-dianysyl- anthrone †	4-CH ₃ OC ₆ H ₄ MgI	2-Methoxy-9,10,10-trianysyl-9,10-dihydro- 9-anthrol	42
3-Methoxy-10,10-dianysyl- anthrone †	4-CH ₃ OC ₆ H ₄ MgI	3-Methoxy-9,10-,10-trianysyl-9,10-dihydro- 9-anthrol	42
C₂₉H₄₆O₃			
7-Ketocholesteryl acetate (6.6 g., 0.015 mole)	CH ₃ MgX (0.1 mole)	7-Hydroxy-7-methylcholesterol (2.25 g.)	297

* The available abstract reports the yields of a series of reactions as ranging from 53% to 75%.

† 2-Methoxy-10,10-dianysylantracen-9(10*H*)-one.

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₉H₄₆O₃ (cont.)			
7-Ketocholesteryl acetate	C ₂ H ₅ MgX	7-Ethylidenecholesterol	297
7-Ketocholesteryl acetate	<i>i</i> -C ₄ H ₉ MgX	7-Hydroxy-7-isobutylcholesterol	297
7-Ketocholesteryl acetate	C ₆ H ₅ MgBr	7-Hydroxy-7-phenylcholesterol	297,274
C₃₀H₄₆O			
<i>trans</i> -Dehydroandrosterone	CH ₃ MgI	17-Methyl-3,17-androstenediol (74%)	154
<i>trans</i> -Dehydroandrosterone (2.0 g.)	CH ₃ MgI (8.0 g. CH ₃ I)	17-Methyl- <i>trans</i> -Δ ^{5,6} -androstene-3,17-diol (1.2 g.)	233
<i>trans</i> -Dehydroandrosterone	C ₂ H ₅ MgI	17-Ethyl-Δ ^{5,6} -androstene-3- <i>trans</i> -17-(?)-diol; Δ ^{5,6} -androstene-3- <i>trans</i> -17- <i>cis</i> -diol	235
C₃₀H₄₆O₂			
Androstane-3,17-dione (100 g.)	CH ₃ MgI (400 mg. CH ₃ I)	3,17-Dimethylandrostande-3,17-diol	233
C₃₀H₄₈O			
Androsterone (0.5 g.)	CH ₃ MgI (2.0 g. CH ₃ I)	3- <i>epi</i> -Hydroxy-17-methylandrostan-17-ol (340 mg.)	233
Androsterone	C ₂ H ₅ MgI	17-Ethyl- <i>cis</i> -androstande-3,17-diol	233
<i>trans</i> -Androsterone	CH ₃ MgI	17-Methyl- <i>trans</i> -androstande-3,17-diol	233
<i>trans</i> -Androsterone	C ₂ H ₅ MgI	17-Ethylandrostande-3- <i>trans</i> -17-(?)-diol; androstande-3- <i>trans</i> -17- <i>cis</i> -diol	233
<i>trans</i> -Androsterone	<i>n</i> -C ₃ H ₇ MgBr	17- <i>n</i> -Propylandrostande-3- <i>trans</i> -17-(?)-diol (very little); androstande-3- <i>trans</i> -17- <i>cis</i> -diol	235
C₃₀H₅₆O₂			
Cyclotriacontane-1,16-dione	CH ₃ MgI	1,16-Dimethylcyclotriacontane-1,16-diol (or partial dehydr'n product)	231

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃₃H₂₂O			
2,3,5,6-Tetraphenylindone	C ₆ H ₅ MgBr	1,2,3,5,6-Pentaphenyl-1-indenol (87%)	3
C₃₃H₂₃OBr			
2-Bromo-2,3,5,6-tetraphenyl-1-indanone (6 g.)	C ₆ H ₅ MgBr (0.1 mole)	2,3,5,6-Tetraphenyl 2,7a-di-hydroinden-1-one (3 g.)	3
2,3,5,6-Tetraphenyl-4-bromo-3a,4-dihydroinden-1-one	CH ₃ MgI	2,3,5,6-Tetraphenyl-7-methyl-3a,7a-dihydroinden-1-one; unidentified products	3
2,3,5,6-Tetraphenyl-4-bromo-3a,4-dihydroinden-1-one	C ₆ H ₅ MgBr	2,3,5,6,7-Pentaphenyl-3a,7a-dihydroinden-1-one; a bimolecular (brominated) comp'd	3
C₃₃H₂₄O			
2,3,5,6-Tetraphenyl-3a,4-dihydroinden-1-one	C ₆ H ₅ MgBr	1,2,3,5,6-Pentaphenyl-3a,4-dihydroinden-1-ol (25%); 2,3,5,6,7-Pentaphenyl-3a,4,7,7a-tetrahydroinden-1-one	3
C₃₄H₂₁O₂Br₃			
2,3,5,6-Tetraphenyl-4,7,7a-tribromo-4,7-methano-3a,4,7,7a-tetrahydroindene-1,8-dione	CH ₃ MgI	1,8-Dihydroxy-1,8-dimethyl-2,3,5,6-tetraphenyl-4,7,7a-tribromo-4,7-methano-3a,4,7,7a-tetrahydrindene	3
C₃₄H₃₄O			
2,2,6,6-Tetrabenzylcyclohexanone (13.5 g.)	CH ₃ MgI (5 equiv.)	Recovered ketone (1 part); 1-methyl-2,2,6,6-tetrabenzylcyclohexanol (2 parts) (Total recovery, 10 g.)	79
C₃₆H₂₈O₂			
2,7-Dimethyl-3,3a,5,6-tetraphenyl-3a,4,7,7a-tetrahydro-4,7-methanoindene-1,8-dione	CH ₃ MgI	2,7,8-Trimethyl-3,3a,5,6-tetraphenyl-8-hydroxy-3a,4,7,7a-tetrahydro-4,7-methanoinden-1-one (90-98%)	7

TABLE VI-XIX (Continued)

<u>Ketone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃₆H₂₈O₂ (cont.)			
2,7-Dimethyl-3,3a,5,6-tetraphenyl-3a,4,7,7a-tetrahydro-4,7-methanoindene-1,8-dione	C ₆ H ₅ MgBr	2,7-Dimethyl-3,3a,5,6,8-pentaphenyl-8-hydroxy-3a,4,7,7a-tetrahydro-4,7-methanoinden-1-one (90-98%)	7
2,7-Dimethyl-3,3a,5,6-tetraphenyl-3a,4,7,7a-tetrahydro-4,7-methanoindene-1,8-dione	4-CH ₃ OC ₆ H ₄ MgBr	2,7-Dimethyl-3,3a,5,6-tetraphenyl-8-hydroxy-8- <i>p</i> -anisyl-3a,4,7,7a-tetrahydro-4,7-methanoinden-1-one (90-98%)	7
C₃₈H₃₂O₂			
2,4,7,7a-Tetramethyl-3,3a,5,6-tetraphenyl-3a,4,7,7a-tetrahydro-4,7-methanoindene-1,8-dione	CH ₃ MgI	1-(or 8-)Hydroxy-1,2,4,7,7a-(or 2,4,7,7a,8-)pentamethyl-3,3a,5,6-tetraphenyl-3a,4,7,7a-tetrahydro-4,7-methanoinden-8-(or 1-)one	7
2,4,7,7a-Tetramethyl-3,3a,5,6-tetraphenyl-3a,4,7,7a-tetrahydro-4,7-methanoindene-1,8-dione	C ₆ H ₅ MgBr	1-(or 8-)Hydroxy-1,3,3a,5,6-(or 3,3a,5,6,8-)pentaphenyl-2,4,7,7a-tetramethyl-3a,4,7,7a-tetrahydro-4,7-methanoinden-8-(or 1-)one	7
2,4,7,7a-Tetramethyl-3,3a,5,6-tetraphenyl-3a,4,7,7a-tetrahydro-4,7-methanoindene-1,8-dione	4-CH ₃ OC ₆ H ₄ MgBr	1-Anisyl-2,5-dimethyl-3,4-diphenylcyclopentadien-1-ol*	7
C₃₉H₂₈O			
2,3,5,6,7-Pentaphenyl-3a,7a-dihydroinden-1-one	C ₆ H ₅ MgBr	1,2,3,5,6,7-Hexaphenyl-3a,7a-dihydroinden-1-ol	3
C₄₄H₄₄O₂			
2,7-Di- <i>n</i> -amyl-3,3a,5,6-tetraphenyl-3a,4,7,7a-tetrahydro-4,7-methanoindene-1,8-dione	C ₆ H ₅ MgBr	2,7-Di- <i>n</i> -amyl-3,3a,5,6,8-pentaphenyl-8-hydroxy-3a,4,7,7a-tetrahydro-4,7-methanoinden-1-one (90-98%)	7

* The diketone is a cyclopentadienone dimer. Evidently depolymerization takes place under the experimental conditions imposed.

REFERENCES FOR TABLE VI-XIX

- (1) Abramov and Malskiĭ, *J. Gen. Chem.*, (U.S.S.R.), 9, 1533-6 (1939); *Chem. Abstr.*, 34, 2839 (1940).
- (2) Aktieselskabet "Ferrosan," Danish Patent 60,592, Feb. 15, 1943; *Chem. Abstr.*, 40, P4086 (1946).
- (3) Allen and Gates, *J. Am. Chem. Soc.*, 64, 2123-7 (1942).
- (4) Allen and Overbaugh, *J. Am. Chem. Soc.*, 57, 740-4 (1935).
- (5) Allen and Overbaugh, *J. Am. Chem. Soc.*, 57, 1322-5 (1935).
- (6) Allen and Van Allan, *J. Am. Chem. Soc.*, 66, 7-8 (1944).
- (7) Allen and Van Allan, *J. Am. Chem. Soc.*, 68, 2387-90 (1946).
- (8) Bachmann and Chemerda, *J. Am. Chem. Soc.*, 61, 2358-61 (1939).
- (9) Bachmann and Levine, *J. Am. Chem. Soc.*, 69, 2341-6 (1947).
- (10) Bachmann, *J. Am. Chem. Soc.*, 52, 3287-90 (1930).
- (11) Bachmann, *J. Am. Chem. Soc.*, 56, 1363-7 (1934).
- (12) Bachmann and Kloetzel, *J. Org. Chem.*, 3, 55-61 (1938).
- (13) Bachmann and Sheehan, *J. Am. Chem. Soc.*, 63, 2598-600 (1941).
- (14) Badger, *J. Chem. Soc.*, 1941, 535-8.
- (15) Badger, Carrington, and Hendry, British Patent 576,962, Apr. 29, 1946; *Chem. Abstr.*, 42, P3782 (1948).
- (16) Baeyer, *Ann.*, 372, 80-151 (1910).
- (17) Banerjee, *Science and Culture*, 12, 508-9 (1947); *Chem. Abstr.*, 41, 6557 (1947).
- (18) Barnett, *J. Chem. Soc.*, 1931, 3340-1.
- (19) Barnett, Cook, and Nixon, *J. Chem. Soc.*, 1927, 504-12.
- (20) Barnett and Sanders, *J. Chem. Soc.*, 1933, 434-7.
- (21) Barrett and Linstead, *J. Chem. Soc.*, 1936, 611-6.
- (22) Bartlett, *J. Am. Chem. Soc.*, 57, 224-7 (1935).
- (23) Bateman and Koch, *J. Chem. Soc.*, 1944, 600-6.
- (24) Béchamp, *Compt. rend.*, 148, 1677-9 (1909); *Chem. Zentr.*, 1909,II, 714.
- (25) Bergmann, *J. Chem. Soc.*, 1938, 1291-2.
- (26) Bergmann and Bergmann, *J. Am. Chem. Soc.*, 59, 1443-50 (1937).
- (27) Bergmann, Eschinazi, and Shapiro, *J. Am. Chem. Soc.*, 64, 557-8 (1942).
- (28) Bergmann and Hirschmann, *J. Org. Chem.*, 4, 40-7 (1939).
- (29) Bergmann, Hoffmann, and Winter, *Ber.*, 66B, 46-54 (1933).
- (30) Bergmann, Shapiro, and Eschinazi, *J. Am. Chem. Soc.*, 64, 559-61 (1942).
- (31) Bergmann and Schreiber, *Ann.*, 500, 118-22 (1933).
- (32) Bergmann and Szmuszhowicz, *J. Am. Chem. Soc.*, 69, 1367-70 (1947).
- (33) Bergmann, Taubadel, and Weiss, *Ber.*, 64B, 1493-1501 (1931).
- (34) Bergmann and Weiss, *Ann.*, 480, 64-75 (1930).
- (35) Bergmann and Weizmann, *J. Org. Chem.*, 4, 266-9 (1939).
- (36) Bergmann and Weizmann, *J. Org. Chem.*, 9, 352-8 (1944).
- (37) Bhattacharyya, *J. Indian Chem. Soc.*, 22, 165-8 (1945); *Chem. Abstr.*, 40, 5044 (1946).
- (38) Billeter and Miescher, *Helv. Chim. Acta*, 29, 859-71 (1946).
- (39) Blicke and Patelski, *J. Am. Chem. Soc.*, 60, 2636-8 (1938).
- (40) Blicke and Patelski, *J. Am. Chem. Soc.*, 60, 2638-41 (1938).
- (41) Blicke and Weinkauff, *J. Am. Chem. Soc.*, 54, 1446-53 (1932).
- (42) Blicke and Weinkauff, *J. Am. Chem. Soc.*, 54, 1460-4 (1932).
- (43) Boedtker, *J. pharm. chim.*, [8], 6, 193-203 (1927); *Chem. Zentr.*, 1927,II, 2189.
- (44) Bogert and Sterling, *Science*, 87, 196, 234 (1938); *Chem. Abstr.*, 32, 4147 (1938).
- (45) Borsche and Menz, *Ber.*, 41, 190-210 (1908).

- (46) Bouveault and Chereau, *Compt. rend.*, 142, 1086-7 (1906); *Chem. Zentr.*, 1906,II, 125.
- (47) Bradfield, Hegde, Rao, Simonsen, and Gillam, *J. Chem. Soc.*, 1936, 667-77.
- (48) Bradfield, Jones, and Simonsen, *J. Chem. Soc.*, 1936, 1137-43.
- (49) Bredt, *J. prakt. Chem.*, [2], 98, 96-105 (1918).
- (50) Bredt-Savelsburg and Buchkremer, *Ber.*, 64B, 600-10 (1931).
- (51) Brunner and Grof, *Monatsh.*, 64, 76-9 (1934).
- (52) Büchi and Jeger, *Helv. Chim. Acta*, 32, 538-44 (1949).
- (53) Bünzly and Decker, *Ber.*, 37, 2931-8 (1904).
- (54) Butenandt, Dannenberg, and von Dresler, *Z. Naturforsch.*, 1, 151-6 (1946); *Chem. Abstr.*, 41, 5887 (1947).
- (55) Butenandt, Dannenberg, and von Dresler, *Z. Naturforsch.*, 1, 222-6 (1946); *Chem. Abstr.*, 41, 5888 (1947).
- (56) Butz, Davis, and Gaddis, *J. Org. Chem.*, 12, 122-32 (1947).
- (57) Buu-Hoï, *Bull. soc. chim.*, [5], 13, 117-23 (1946).
- (58) Campbell and Soffer, *J. Am. Chem. Soc.*, 64, 417-25 (1943).
- (59) Candini, *Gazz. chim. ital.*, 64, 594-604 (1934); *Chem. Abstr.*, 29, 1408 (1935).
- (60) Charrier and Ghigi, *Gazz. chim. ital.*, 62, 928-36 (1932); *Chem. Abstr.*, 27, 1344 (1933).
- (61) Charrier and Ghigi, *Ber.*, 69B, 2211-32 (1936).
- (62) Chatterjee, *J. Indian Chem. Soc.*, 12, 591-4 (1935).
- (63) Chavanne and Miller, *Bull. soc. chim. Belg.*, 39, 287-97 (1930).
- (64) Chigi, *Ber.*, 71B, 684-9 (1938).
- (65) Chinaeva and Ushakov, *J. Gen. Chem. (U.S.S.R.)*, 11, 335-8 (1941); *Chem. Abstr.*, 35, 5903 (1941).
- (66) Choin, *J. Russ. Phys.-Chem. Soc.*, 44, 1844-53 (1912); *Chem. Zentr.*, 1913,I 1421.
- (67) Clar, *Ber.*, 62B, 350-9 (1929).
- (68) Clar, *Ber.*, 65B, 846-58 (1932).
- (69) Clar and Wright, *Nature*, 163, 921-2 (1949).
- (70) Clarke and Francis, *Ber.*, 45, 2060-5 (1912).
- (71) Clarkson and Gomberg, *J. Am. Chem. Soc.*, 52, 2881-91 (1930).
- (72) Clemo and Metcalfe, *J. Chem. Soc.*, 1937, 1518-23.
- (73) Cook, *J. Chem. Soc.*, 1932, 456-72.
- (74) Cook and Lawrence, *J. Chem. Soc.*, 1936, 1431-4.
- (75) Cook and Hewett, *J. Chem. Soc.*, 1933, 398-405.
- (76) Cook and Hewett, *J. Chem. Soc.*, 1936, 62-71.
- (77) Mikeska and Cohen, *J. Org. Chem.*, 6, 787-94 (1941).
- (78) Cook and Robinson, *J. Chem. Soc.*, 1938, 505-13.
- (79) Cornubert, Borrel, De Demo, Garner, Humeau, Le Bihan, and Sarkis, *Bull. soc. chim.*, [5], 2, 195-220 (1935).
- (80) Courtot, *Ann. chim.*, [9], 4, 58-136 (1915).
- (81) Crossley and Gilling, *J. Chem. Soc.*, 97, 2218-23 (1910).
- (82) Decker, *Ber.*, 38, 2493-511 (1905).
- (83) Decker and von Fellenberg, *Ann.*, 356, 281-342 (1907).
- (84) Denisenko and Naber, *Bull. acad. sci. U. R. S. S., Classe sci. math. nat., Ser. chim.*, 1938, 1015-8; *Chem. Abstr.*, 33, 7280 (1939).
- (85) Dev, *Current Sci.*, 16, 377-8 (1947); *Chem. Abstr.*, 42, 5890 (1948).
- (86) Dev, *J. Indian Chem. Soc.*, 25, 69-80 (1948).
- (87) Dev, *J. Indian Chem. Soc.*, 25, 315-22 (1948).
- (88) Dilthey and Stephen, *J. prakt. Chem.*, [2], 152, 114-25 (1939).
- (89) Dimroth and Stockstrom, *Ber.*, 75B, 180-97 (1942).

- (90) Dimroth and Stockstrom, *Ber.*, 75B, 326-31 (1942).
(91) Dimroth and Stockstrom, *Ber.*, 75B, 510-21 (1942).
(92) Dœuvre, *Bull. soc. chim.*, [5], 6, 1067-9 (1939).
(93) Dufraisse, Velluz, and Velluz, *Bull. soc. chim.*, [5], 4, 1260-4 (1937).
(94) Dulou, *Bull. inst. pin.*, 1934, 164-5, 178-82, 197-204; *Chem. Abstr.*, 29, 2945 (1935).
(95) Dupont, *Ann. chim.*, [8], 30, 485-587 (1913).
(96) Elagina and Zelinskiĭ, *Compt. rend. acad. sci. U. R. S. S.*, 30, 728-31 (1941); *Chem. Abstr.*, 37, 616 (1943).
(97) Elliott and Linstead, *J. Chem. Soc.*, 1938, 660-5.
(98) Erickson and Kitchens, *J. Am. Chem. Soc.*, 68, 492-6 (1946).
(99) Errington and Linstead, *J. Chem. Soc.*, 1938, 666-72.
(100) Étienne and Brisson, *Compt. rend.*, 224, 1775-7 (1947); *Chem. Abstr.*, 42, 1259, (1948).
(101) Fieser and Fieser, *J. Am. Chem. Soc.*, 57, 782-3 (1935).
(102) Fieser and Hershberg, *J. Am. Chem. Soc.*, 61, 1272-81 (1939).
(103) Fieser and Heymann, *J. Am. Chem. Soc.*, 64, 376-82 (1942).
(104) Fieser and Johnson, *J. Am. Chem. Soc.*, 61, 168-71 (1939).
(105) Fieser and Szmuszkowicz, *J. Am. Chem. Soc.*, 70, 3352-5 (1948).
(106) Gversiteli and Pataraya, *J. Gen. Chem. (U.S.S.R.)*, 19, 1479-82 (1949); *Chem. Abstr.*, 44, 1038 (1950).
(107) Geissman and Morris, *J. Am. Chem. Soc.*, 66, 716-9 (1944).
(108) Geissman and Tulagin, *J. Am. Chem. Soc.*, 63, 3352-6 (1941).
(109) Geissman and Tulagin, *J. Am. Chem. Soc.*, 66, 719-22 (1944).
(110) Godchot and Bedos, *Compt. rend.*, 180, 751-4 (1925).
(111) Godchot and Bedos, *Bull. soc. chim.*, [4], 39, 83-99 (1926).
(112) Gomberg and Cone, *Ann.*, 370, 142-208 (1909).
(113) Grateau, *Compt. rend.*, 196, 1619-21 (1933).
(114) Grewe, *Ber.*, 72B, 785-90 (1939).
(115) Grewe, *Ber.*, 72B, 1314-7 (1939).
(116) Grignard, *Ann. Univ. Lyon, N.S.*, 6, 1-116 (1901); *Chem. Zentr.*, 1901, 11, 622.
(117) Grignard and Savard, *Compt. rend.*, 181, 589-92 (1925).
(118) Grignard and Savard, *Bull. soc. chim. Belg.*, 36, 97-107 (1927).
(119) Gripenberg, *Suomen Kemistilehti*, 18B, 53-6 (1945); *Chem. Abstr.*, 41, 739 (1947).
(120) Gripenberg, *Suomen Kemistilehti*, 19B, 46-9 (1946); *Chem. Abstr.*, 41, 5488 (1947).
(121) Haberland and Heinrich, *Ber.*, 72B, 1222-6 (1939).
(122) Haller and Bauer, *Compt. rend.*, 142, 971-6 (1906); *Chem. Zentr.*, 1906, 1, 1827.
(123) Haller and Guyot, *Bull. soc. chim.*, [3], 31, 979-85 (1904).
(124) Harris, *J. Am. Chem. Soc.*, 51, 2591 (1929).
(125) Harris, *J. Am. Chem. Soc.*, 64, 720 (1942).
(126) Harris and Sanderson, *J. Am. Chem. Soc.*, 70, 339-43 (1948).
(127) Haworth, *J. Chem. Soc.*, 103, 1242-50 (1913).
(128) Haworth, *J. Chem. Soc.*, 1932, 1125-33.
(129) Haworth and Barker, *J. Chem. Soc.*, 1939, 1299-303.
(130) Haworth and Mavin, *J. Chem. Soc.*, 1932, 2720-3.
(131) Haworth and Sheldrick, *J. Chem. Soc.*, 1934, 1950-2.
(132) Hill, Short, and Stromberg, *J. Chem. Soc.*, 1937, 937-41.
(133) Holmes and Mann, *J. Am. Chem. Soc.*, 69, 2000-3 (1947).
(134) Hooker and Fieser, *J. Am. Chem. Soc.*, 58, 1216-23 (1936).

- (135) Hosking, *Ber.*, 69B, 780-5 (1936).
- (136) Hunter and Hogg, *J. Am. Chem. Soc.*, 68, 1676-7 (1946).
- (137) Hunter and Korman, *J. Am. Chem. Soc.*, 69, 2124-6 (1947).
- (138) Hurd, Jones, and Blunck, *J. Am. Chem. Soc.*, 57, 2033-6 (1935).
- (139) Inagaki, *J. Pharm. Soc. Japan*, 59, 5-17 (1939); *Chem. Abstr.*, 33, 3790 (1939).
- (140) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 34, 100-2 (1902); *Bull. soc. chim.*, [3], 28, 922 (1902).
- (141) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 35, 1269-75 (1905); *Bull. soc. chim.*, [3], 34, 181 (1905).
- (142) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 36, 1545-51 (1904); *Bull. soc. chim.*, [3], 36, 177 (1906).
- (143) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 38, 252-3 (1906); *Bull. soc. chim.*, [4], 4, 981, (1908).
- (144) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 38, 656-9 (1906); *Bull. soc. chim.*, [4], 4, 1203 (1908).
- (145) Ivanoff and Spasoff, *Bull. soc. chim.*, [4], 49, 377-9 (1931).
- (146) Ivanoff and Spasoff, *Bull. soc. chim.*, [5], 2, 1435-8 (1935).
- (147) Jaworski, *J. Russ. Phys.-Chem. Soc.*, 40, 1746-8 (1909); *Chem. Zentr.*, 1909,I, 856.
- (148) Julian, Cole, and Wood, *J. Am. Chem. Soc.*, 57, 2508-13 (1935).
- (149) Julian, Cole, and Schroeder, *J. Am. Chem. Soc.*, 71, 2368-70 (1949).
- (150) Julian and Gist, *J. Am. Chem. Soc.*, 57, 2030-2 (1935).
- (151) Kharasch and Burt, *J. Org. Chem.*, 16, 150-60 (1951).
- (152) Kharasch and Sternfeld, *J. Am. Chem. Soc.*, 61, 2318-22 (1939).
- (153) Kharasch and Tawney, *J. Am. Chem. Soc.*, 63, 2308-15 (1941).
- (154) Kiprianov and Frenkel, *J. Gen. Chem. (U.S.S.R.)*, 9, 1682-6 (1939); *Chem. Abstr.*, 34, 3756 (1940).
- (155) Klages, *Ber.*, 40, 2360-76 (1907).
- (156) Klages and Sommer, *Ber.*, 39, 2306-15 (1906).
- (157) Kleene, *J. Am. Chem. Soc.*, 63, 1768 (1941).
- (158) Kloetzel and Close, *J. Org. Chem.*, 11, 395-8 (1946).
- (159) Koelsch, *J. Am. Chem. Soc.*, 54, 4744-9 (1932).
- (160) Koelsch, *J. Am. Chem. Soc.*, 55, 3394-9 (1933).
- (161) Koelsch, *J. Am. Chem. Soc.*, 56, 1337-9 (1934).
- (162) Koelsch and Johnson, *J. Am. Chem. Soc.*, 65, 567-73 (1943).
- (163) Koelsch and Richter, *J. Org. Chem.*, 3, 462-4 (1938).
- (164) Kohler, *Am. Chem. J.*, 37, 369-92 (1907).
- (165) Kohler and Blanchard, *J. Am. Chem. Soc.*, 57, 367-71 (1935).
- (166) Kohn, *Monatsh.*, 31, 747-51 (1910).
- (167) Kohn and Ostersetzer, *Monatsh.*, 32, 905-16 (1911).
- (168) Komppa, *Ann.*, 472, 179-84 (1929).
- (169) Komppa and Roschier, *Ann. Acad. Sci. Fennica (A)* 10, III, 3-15 (1916); *Chem. Zentr.*, 1917,I, 751; *Chem. Abstr.*, 11, 3276 (1917).
- (170) Kon and Woolman, *J. Chem. Soc.*, 1939, 794-800.
- (171) Konowalow, Miller, and Timtschenko, *J. Russ. Phys.-Chem. Soc.*, 38, 447-8 (1906); *Chem. Zentr.*, 1906,II, 311.
- (172) Kotz, Blendermann, Rosenbusch, and Sirringhaus, *Ann.*, 400, 55-72 (1913).
- (173) Kovache, *Ann. chim.*, [9], 10, 184-248 (1918).
- (174) Krollpfeiffer and Branscheid, *Ber.*, 56B, 1617-9 (1923).
- (175) Lee, Ziering, Berger, and Heineman, *Jubilee Vol. Emil Barell*, 1946, 264-305; *Chem. Abstr.*, 41, 6246 (1947).
- (176) Lee, Ziering, Heineman, and Berger, *J. Org. Chem.*, 12, 885-93 (1947).

- (177) Le Fevre and Pearson, *J. Chem. Soc.*, 1933, 482-4.
(178) Lehmstedt and Dostal, *Ber.*, 72B, 804-6 (1939).
(179) Leroide, *Ann. chim.*, [9], 16, 354-410 (1921).
(180) Leuchs and Lock, *Ber.*, 48, 1432-43 (1915).
(181) Löwenbein, Pongrácz, and Spiess, *Ber.*, 57B, 1517-26 (1924).
(182) Lukeš, *Collection Czechoslov. Chem. Commun.*, 4, 181-92 (1932); *Chem. Zentr.*, 1932,II, 873; *Chem. Abstr.*, 26, 4328 (1932).
(183) Lukeš and Smetáčková, *Collection Czechoslov. Chem. Commun.*, 6, 433 (1934); *Chem. Abstr.*, 29, 794 (1935).
(184) Lüttringhaus and Sholtis, *Ann.*, 557, 70-82 (1945).
(185) Malmgren, *Ber.*, 35, 3910-2 (1902).
(186) Mailhe and Murat, *Bull. soc. chim.*, [4], 7, 1083-9 (1910).
(187) Marvel and Brooks, *J. Am. Chem. Soc.*, 63, 2853 (1941).
(188) Marvel and Walton, *J. Org. Chem.*, 7, 88-97 (1942).
(189) Marxer, *Helv. Chim. Acta*, 24, 209-15E (1941).
(190) Matzurewitsch, *J. Russ. Phys.-Chem. Soc.*, 43, 973-90 (1911); *Chem. Abstr.*, 6, 480 (1912).
(191) Maxim, Zugrăvescu, and Teodorescu, *Bull. soc. chim.*, [5], 7, 382-93 (1940).
(192) Maxim, Zugrăvescu, and Teodorescu, *Bul. Chim. pură apl., Soc. Chim. România*, [2], 3, A24-31 (1941-1942); *Chem. Zentr.*, 1943,II, 1278.
(193) Mentzer, Molho, and Xuong, *Bull. soc. chim.*, [5], 15, 263-8 (1948).
(194) Mentzer and Urbain, *Compt. rend.*, 215, 554-6 (1942); *Chem. Abstr.*, 38, 2645 (1944).
(195) Miescher, U. S. Patent 2,435,013, Jan. 27, 1948; *Chem. Abstr.*, 42, P2996 (1948).
(196) Miescher, Heer, and Billeter, U.S. Patent 2,459,834, Jan. 25, 1949; *Chem. Abstr.*, 43, P3848 (1949).
(197) Miescher and Marxer, U. S. Patent 2,411,664, Nov. 26, 1946; *Chem. Abstr.*, 41, P6276 (1947).
(198) Mikhaïlov and Blokhina, *J. Gen. Chem. (U.S.S.R.)*, 13, 609-15 (1943); *Chem. Abstr.*, 39, 702 (1945).
(199) Milas, U. S. Patent 2,407,672, Sept. 17, 1946; *Chem. Abstr.*, 41, P996 (1947).
(200) Minnis, *J. Am. Chem. Soc.*, 51, 2143-7 (1929).
(201) Mitchovitch, *Compt. rend.*, 200, 1601-3 (1935).
(202) Mitter and De, *J. Indian Chem. Soc.*, 16, 35-42 (1939).
(203) Mitter and De, *J. Indian Chem. Soc.*, 16, 199-208 (1939).
(204) Murat, *Ann. chim.*, [8], 16, 108-26 (1909).
(205) Murat, *J. pharm. chim.*, 4, 294-9 (1911); *J. Soc. Chem. Ind.*, 30, 1332 (1911); *Chem. Abstr.*, 6, 1156 (1912).
(206) Myers and Lindwall, *J. Am. Chem. Soc.*, 60, 2153-5 (1938).
(207) Nakanishi, *Proc. Imp. Acad. (Tokyo)*, 9, 394-7 (1933); *Chem. Abstr.*, 28, 762 (1934).
(208) Nametkin and Shawrigin, *Ber.*, 66B, 511-4 (1933).
(209) Natelson and Gottfried, *J. Am. Chem. Soc.*, 61, 1001-2 (1939).
(210) Newman, *J. Org. Chem.*, 9, 518-28 (1944).
(211) Newman and Booth, *J. Org. Chem.*, 12, 737-9 (1947).
(212) Newman and Farbman, *J. Am. Chem. Soc.*, 66, 1550-2 (1944).
(213) Newman and Hart, *J. Am. Chem. Soc.*, 69, 298-30 (1947).
(214) Nyman and Kuvaja, *Ann.*, 538, 68-84 (1939).
(215) Orchin, *J. Am. Chem. Soc.*, 68, 571-2 (1946).
(216) Orchin and Reggel, *J. Am. Chem. Soc.*, 69, 505-9 (1947).

- (217) Perkin, *Proc. Chem. Soc.*, 21, 255-6 (1905).
- (218) Perlman, Davidson, and Bogert, *J. Org. Chem.*, 1, 288-99 (1936).
- (219) Petrov and Chel'tsova, *J. Gen. Chem. (U.S.S.R.)*, 12, 87-94 (1942); *Chem. Abstr.*, 37, 1993 (1943).
- (220) Plattner and Magyar, *Helv. Chim. Acta*, 25, 581-90 (1942).
- (221) Reilly and Drumm, *J. Chem. Soc.*, 1930, 455-8.
- (222) Richet, *Ann. chim.*, [12], 3, 317-54 (1948).
- (223) Robinson and Slater, *J. Chem. Soc.*, 1941, 376-85.
- (224) Royer, *Ann. chim.*, [12], 1, 395-445 (1946).
- (225) Royer and Buu-Hoï, *Compt. rend.*, 222, 746-7 (1946); *Chem. Abstr.*, 40, 4051 (1946).
- (226) Rupe and Ebert, *Ber.*, 41, 2067-71 (1908).
- (227) Rupe and Emmerich, *Ber.*, 41, 1393-403 (1908).
- (228) Rupe and Emmerich, *Ber.*, 41, 1750-4 (1908).
- (229) Rupe and Liechtenhahn, *Ber.*, 39, 1119-26 (1906).
- (230) Rupe and Tomi, *Ber.*, 47, 3064-93 (1914).
- (231) Ruzicka and Boekenoogen, *Helv. Chim. Acta*, 14, 1319-35 (1931).
- (232) Ruzicka, Ehmman, and Morgeli, *Helv. Chim. Acta*, 16, 314-26 (1933).
- (233) Ruzicka, Goldberg, and Rosenberg, *Helv. Chim. Acta*, 18, 1487-98 (1935).
- (234) Ruzicka and Hofmann, *Helv. Chim. Acta*, 22, 126-34 (1939).
- (235) Ruzicka and Rosenberg, *Helv. Chim. Acta*, 19, 357-66 (1936).
- (236) Ruzicka and Seidel, *Helv. Chim. Acta*, 19, 424-33 (1936).
- (237) Ruzicka and Waldmann, *Helv. Chim. Acta*, 15, 907-14 (1932).
- (238) Ruzicka, Zwicky, and Jeger, *Helv. Chim. Acta*, 31, 2143-7 (1948).
- (239) Sabatier and Mailhe, *Compt. rend.*, 138, 1321-4 (1904); *J. Chem. Soc.*, 86, 1, 666, (1904).
- (240) Sabatier and Mailhe, *Compt. rend.*, 141, 20-22 (1905); *Chem. Zentr.*, 1905, II, 482.
- (241) Sabatier and Mailhe, *Compt. rend.*, 141, 298-301 (1905); *J. Chem. Soc.*, 88, 1, 254, (1905).
- (242) Sabatier and Mailhe, *Compt. rend.*, 142, 438-40 (1906); *Chem. Zentr.*, 1906, I, 1096.
- (243) Sachs and Kantorowicz, *Ber.*, 42, 1565-76 (1909).
- (244) St. Pfau and Plattner, *Helv. Chim. Acta*, 19, 858-79 (1936).
- (245) Semmler, Jonas, and Oelsner, *Ber.*, 50, 1838-42 (1917).
- (246) Sherwood, Short, and Stansfield, *J. Chem. Soc.*, 1932, 1832-5.
- (247) Schiessler, Rytina, and Whitmore, *J. Am. Chem. Soc.*, 70, 529-30 (1948).
- (248) Schlenk and Herzenstein, *Ann.*, 372, 21-31 (1910).
- (249) Schmidt, *Jahrbuch der organischen Chemie*, I, 218 (1907).
- (250) Schmitt, *Ann.*, 547, 256-70 (1941).
- (251) Schneider and Spielman, *J. Biol. Chem.*, 142, 345-54 (1942).
- (252) Schönberg and Asker, *J. Chem. Soc.*, 1946, 609-10.
- (253) Sen and Sidhu, *J. Indian Chem. Soc.*, 25, 437-8 (1948).
- (254) Sieglitz and Marx, *Ber.*, 56B, 1619-21 (1923).
- (255) Signaigo and Cramer, *J. Am. Chem. Soc.*, 55, 3326-32 (1933).
- (256) Simonis and Kirschsten, *Ber.*, 45, 567-79 (1912).
- (257) Smith and Hanson, *J. Am. Chem. Soc.*, 57, 1326-8 (1935).
- (258) Soc. pour l'ind. chim. à Bâle, British Patent 591,994, Sept. 4, 1947; *Chem. Abstr.*, 42, P1609 (1948).
- (259) Šorm, *Collection Czech. Chem. Commun.*, 12, 251-61 (1947); *Chem. Abstr.*, 42, 555 (1948).
- (260) Šorm and Fajkoš, *Collection Czech. Chem. Commun.*, 12, 81-100 (1947); *Chem. Abstr.*, 41, 4140 (1947).

- (261) Staudinger and Rheiner, *Helv. Chim. Acta*, 7, 8-18 (1924).
(262) Stoermer and Laage, *Ber.*, 50, 981-9 (1917).
(263) Sulzbacher and Bachmann, *J. Org. Chem.*, 13, 303-8 (1948).
(264) Sumpter, *Trans. Kentucky Acad. Sci.*, 9, 61-4 (1941); *Chem. Abstr.*, 36, 4508 (1942).
(265) Thiele and Weitz, *Ann.*, 377, 1-22 (1910).
(266) Tiffeneau and Tchoubar, *Compt. rend.*, 198, 941-3 (1934).
(267) Tiffeneau, Tchoubar, and Le Tellier, *Compt. rend.*, 216, 856-60 (1943); *Chem. Abstr.*, 38, 4584 (1944).
(268) Treibs, *Ber.*, 65B, 1324-9 (1932).
(269) Tschitschibabin, *J. Russ. Phys.-Chem. Soc.*, 45, 184-8 (1913); *Chem. Zentr.*, 1913, I, 2028.
(270) Ullmann and Engi, *Ber.*, 37, 2367-74 (1904).
(271) Ullmann and Mourawiew-Winogradoff, *Ber.*, 38, 2213-9 (1905).
(272) Ullmann and von Wurstemberger, *Ber.*, 37, 73-8 (1904).
(273) Ullmann and von Wurstemberger, *Ber.*, 38, 4105-10 (1905).
(274) Urushibara, Ando, Araki, and Ozawa, *Bull. Chem. Soc., Japan*, 12, 353-5 (1937); *Chem. Abstr.*, 31, 7881 (1937).
(275) Vavon and Guédon, *Bull. soc. chim.*, [4], 47, 901-10 (1930).
(276) Vavon and Mitchovitch, *Bull. soc. chim.*, [4], 45, 961-72 (1929).
(277) Vavon and Perlin-Borrel, *Bull. soc. chim.*, [4], 51, 993-4 (1932).
(278) von Auwers, *Ber.*, 38, 1697-711 (1905).
(279) von Auwers, *Ber.*, 49, 2389-410 (1916).
(280) von Auwers and Eisenlohr, *Ber.*, 43, 827-34 (1910).
(281) von Auwers and Ellinger, *Ann.*, 387, 200-39 (1912).
(282) von Auwers and Hessenland, *Ann.*, 352, 273-87 (1907).
(283) von Auwers and Keil, *Ber.*, 36, 1861-77 (1903).
(284) von Auwers and Kockritz, *Ann.*, 352, 288-321 (1907).
(285) von Auwers and Krollpfeiffer, *Ber.*, 48, 1226-33 (1915).
(286) von Auwers and Lange, *Ann.*, 401, 303-26 (1911).
(287) von Auwers and Treppmann, *Ber.*, 48, 1207-25 (1915).
(288) von Braun and Anton, *Ber.*, 67B, 1051-6 (1934).
(289) von Braun and Kirschbaum, *Ber.*, 46, 3041-50 (1913).
(290) von Braun and Kirschbaum, *Ber.*, 52B, 1725-30 (1919).
(291) Wallach, *Ann.*, 345, 139-54 (1906).
(292) Wallach, *Ann.*, 356, 227-49 (1907).
(293) Wallach, *Ann.*, 359, 265-86 (1908).
(294) Wallach, *Ann.*, 396, 264-84 (1913).
(295) Wanin, *J. Russ. Phys.-Chem. Soc.*, 44, 1068-75 (1912); *Chem. Zentr.*, 1913, I, 24.
(296) Wedekind and Miller, *Ber.*, 44, 3285-7 (1911).
(297) Weinhouse and Kharasch, *J. Org. Chem.*, 1, 490-5 (1936).
(298) Weiss and Alberti, *Monatsh.*, 59, 220-7 (1932).
(299) Weiss and Knapp, *Monatsh.*, 61, 61-8 (1932).
(300) Weiss and Luft, *Monatsh.*, 48, 337-45 (1927).
(301) Weiss and Woidich, *Monatsh.*, 46, 453-8 (1925).
(302) Willemart, *Compt. rend.*, 207, 536-8 (1938); *Chem. Abstr.*, 33, 571 (1939).
(303) Williams and Edwards, *J. Am. Chem. Soc.*, 69, 336-8 (1947).
(304) Wolff, *Compt. rend.*, 172, 1357-60 (1921).
(305) Wolff, *Ann. chim.*, [9], 20, 82-130 (1923).
(306) Leroide, *Compt. rend.*, 148, 1611-3 (1909); *Chem. Abstr.*, 3, 2675 (1909).
(307) Woods, *J. Am. Chem. Soc.*, 69, 2549-52 (1947).
(308) Woods, Griswold, Armbrecht, Blumethal, and Plapinger, *J. Am. Chem. Soc.*, 71, 2028-31 (1949).

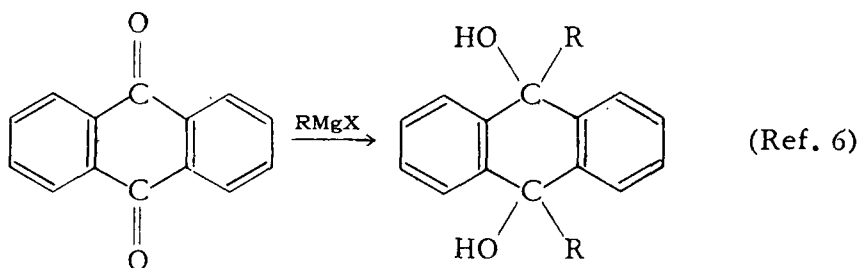
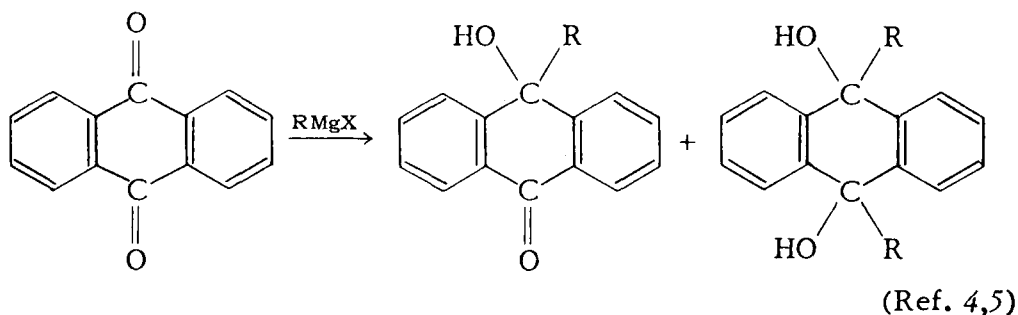
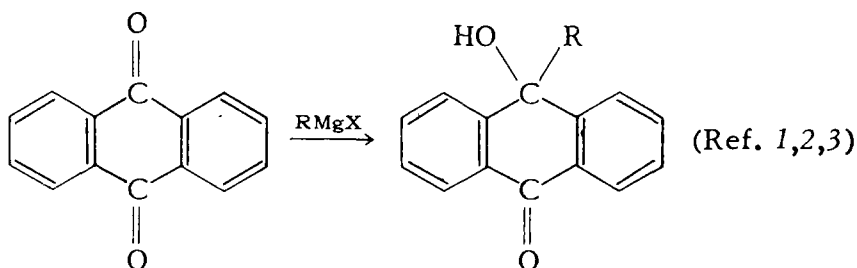
- (309) Woods and Reed, *J. Am. Chem. Soc.*, 71, 1348-50 (1949).
(310) Woods and Tucker, *J. Am. Chem. Soc.*, 70, 2174-7 (1948).
(311) Zeile and Meyer, *Ber.*, 75B, 356-62 (1942).
(312) Zelinsky, *Ber.*, 34, 3877-84 (1901).
(313) Zelinsky, *Ber.*, 34, 3950-2 (1901).
(314) Zelinsky, *Ber.*, 58B, 2755-63 (1925).
(315) Zelinsky and Glinka, *J. Russ. Phys.-Chem. Soc.*, 39, 1170 (1908); *Chem. Abstr.*, 2, 1265 (1908).
(316) Zelinsky and Gutt, *Ber.*, 35, 2140-4 (1902).
(317) Zerner and Loti, *Monatsh.*, 34, 981-94 (1913).
(318) Zelinsky, Michlina, and Eventowa, *Ber.*, 66B, 1422-6 (1933).
(319) Zelinsky and Namjetkin, *Ber.*, 35, 2683 (1902).
(320) Ziegler, *Ann.*, 434, 34-78 (1923).
(321) Ziegler and Ochs, *Ber.*, 54B, 3003-9 (1921).
(322) Ziegler and Ochs, *Ber.*, 55B, 2257-77 (1922).
(323) Ziering, Berger, Heineman, and Lee, *J. Org. Chem.*, 12, 894-903 (1947).
(324) Zincke and Schwabe, *Ber.*, 41, 897-902 (1908).
(325) Koelsch, *J. Am. Chem. Soc.*, 54, 3384-9 (1932).
(326) Crawford, *J. Am. Chem. Soc.*, 61, 3310-4 (1939).
(327) Gandini, *Gazz. chim. ital.*, 64, 594-604 (1934); *Chem. Abstr.*, 29, 1408 (1935).
(328) Obtemperanskaya, *Vestnik Moskov. Univ.*, 1946, No. 3/4, 132-42; *Chem. Abstr.*, 42, 4554 (1948).
(329) Schönberg and Ismail, *J. Chem. Soc.*, 1945, 201-2.
(330) Birch and Robinson, *J. Chem. Soc.*, 1943, 501-2.
(331) Büchi, Jeger, and Ruzicka, *Helv. Chim. Acta*, 31, 241-8 (1948).
(332) Stoll and Commarmont, *Helv. Chim. Acta*, 31, 554-5 (1948).
(333) Birch and Robinson, *J. Chem. Soc.*, 1944, 503-6.
(334) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 34, 242-4 (1902); *Bull. soc. chim.*, [3], 30, 210 (1903).
(335) Treibs, *Ber.*, 77B, 572-9 (1944).
(336) Ghosh, *Science and Culture*, 3, 120-1 (1937); *Chem. Abstr.*, 32, 145 (1938).
(337) Whitmore and Pedlow, *J. Am. Chem. Soc.*, 63, 758-60 (1941).
(338) Alexander and Coraor, *J. Am. Chem. Soc.*, 73, 2721-3 (1951).
(339) Reimer and Reynolds, *Am. Chem. J.*, 40, 428-44 (1908).
(340) French and Smith, *J. Am. Chem. Soc.*, 67, 1949-50 (1945).
(341) Koelsch, *J. Am. Chem. Soc.*, 58, 1331-3 (1935).
(342) Mousseron and Winternitz, *Bull. soc. chim.*, [5], 13, 604-10 (1946).
(343) Crane, Boord, and Henne, *J. Am. Chem. Soc.*, 67, 1237-9 (1945).
(344) Zal'kind and Gverdtsiteli, *J. Gen. Chem. (U.S.S.R.)*, 9, 855-62; *Chem. Abstr.*, 34, 387 (1940).
(345) Schokina, Kildischeva, and Preobrashenski, *J. Gen. Chem. (U.S.S.R.)*, 11, 425-8 (1941); *Brit. Chem. Abstr.*, A, 11, 224 (1942).
(346) von Auwers and Peters, *Ber.*, 43, 3076-94 (1910).
(347) Cymerman, Heilbron, and Jones, *J. Chem. Soc.*, 1945, 90-4.
(348) Semon and Craig, *J. Am. Chem. Soc.*, 58, 1278-82 (1936).
(349) Ullmann and Maag, *Ber.*, 40, 2515-24 (1907).
(350) Chavanne and Becker, *Bull. soc. chim. Belg.*, 36, 591-604 (1927).
(351) Meerwein, *Ann.*, 405, 129-75 (1914).
(352) Pines and Ipatieff, *J. Am. Chem. Soc.*, 61, 1076-7 (1939).
(353) Wallach, *Ann.*, 365, 255-77 (1909).
(354) Zelinsky and Pappe, *J. Russ. Phys.-Chem. Soc.*, 37, 625-6 (1905); *Bull. soc. chim.*, [4], 2, 1119 (1907).
(355) Dupont, *Compt. rend.*, 152, 1486-8 (1911); *Chem. Abstr.*, 5, 3408 (1911).

- (356) Dupont, *Compt. rend.*, 154, 599-601 (1912); *Chem. Abstr.*, 6, 1287 (1912).
- (357) Koelsch and Wawzonek, *J. Org. Chem.*, 6, 684-9 (1941).
- (358) Berge, Wittfeld, and Wildt, *Ber.*, 67B, 238-44 (1934).
- (359) Chavanne and de Vogel, *Bull. soc. chim. Belg.*, 37, 141-52 (1928).
- (360) Bergmann and Blum-Bergmann, *J. Am. Chem. Soc.*, 58, 1678-81 (1936).
- (361) van Rysselberge, *Bull. acad. roy. Belg., Classe sci.*, [5], 12, 171-92 (1926); *Chem. Zentr.*, 1926, 11, 1846.
- (362) Cook and Hewett, *J. Chem. Soc.*, 1933, 1098-111.
- (363) Cohen, Cook, Hewett, and Girard, *J. Chem. Soc.*, 1934, 653-8.
- (364) Fieser and Rigaudy, *J. Am. Chem. Soc.*, 73, 4660-2 (1951).

CHAPTER VII

Reactions of Grignard Reagents with Quinones

Whereas the true quinones are in fact bifunctional α,β -unsaturated cyclic ketones, they undergo many of the reactions already discussed in Chapter VI. Single and double 1,2-addition, 1,4-addition, and combined 1,2- and 1,4-addition have all been reported.



¹Julian, Cole, and Wood, *J. Am. Chem. Soc.*, 57, 2508-13 (1935).

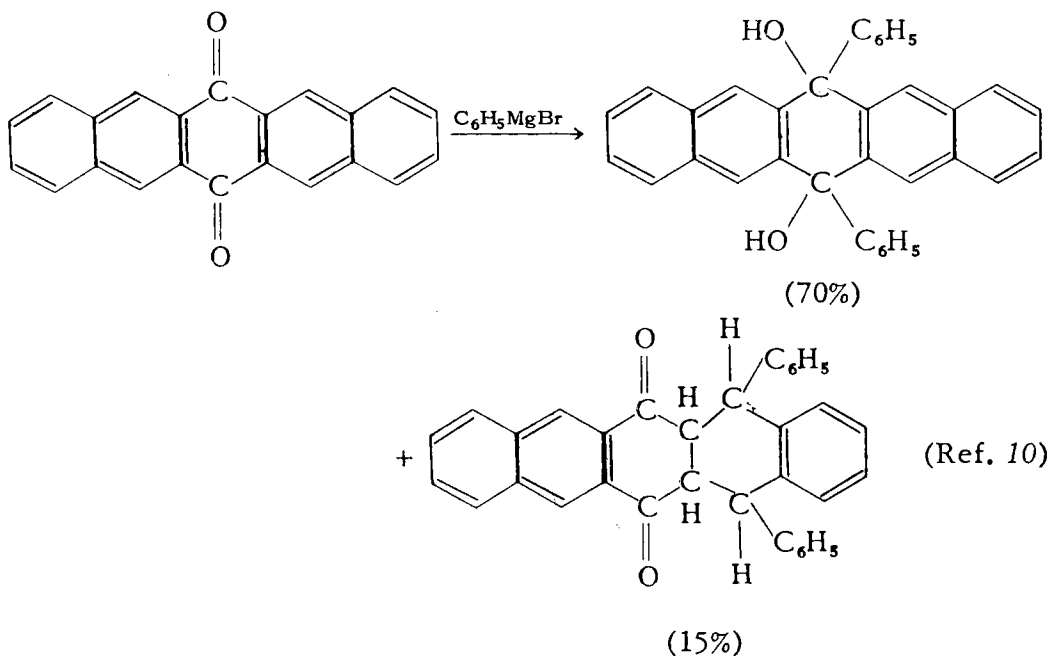
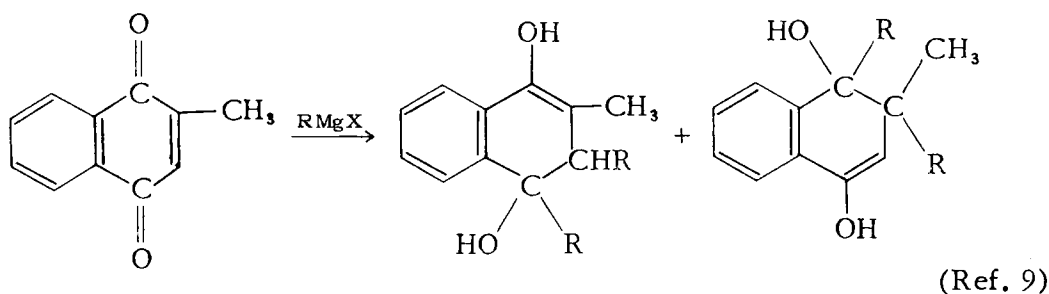
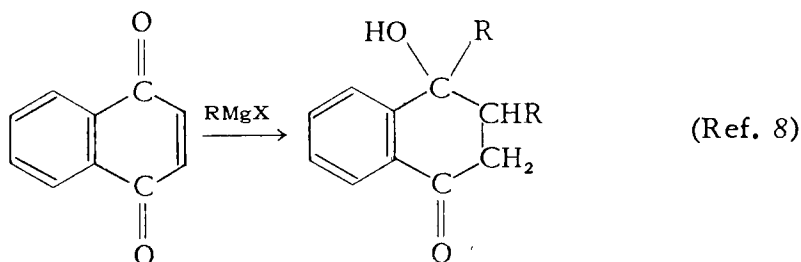
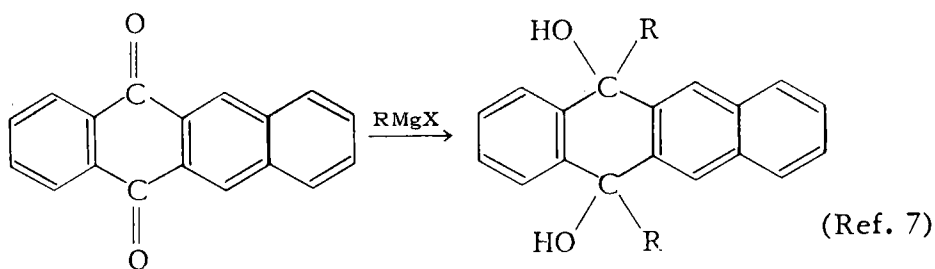
²Haller and Guyot, *Compt. rend.*, 138, 1251-4 (1904); *Chem. Zentr.*, 1904,II, 117.

³Blicke and Weinkauff, *J. Am. Chem. Soc.*, 54, 1460-4 (1932).

⁴Padova, *Ann. chim.*, [8], 19, 353-440 (1910).

⁵Guyot and Staehling, *Bull. soc. chim.*, [3], 33, 1104-21 (1905).

⁶Clarkson and Gomberg, *J. Am. Chem. Soc.*, 52, 2881-91 (1930).

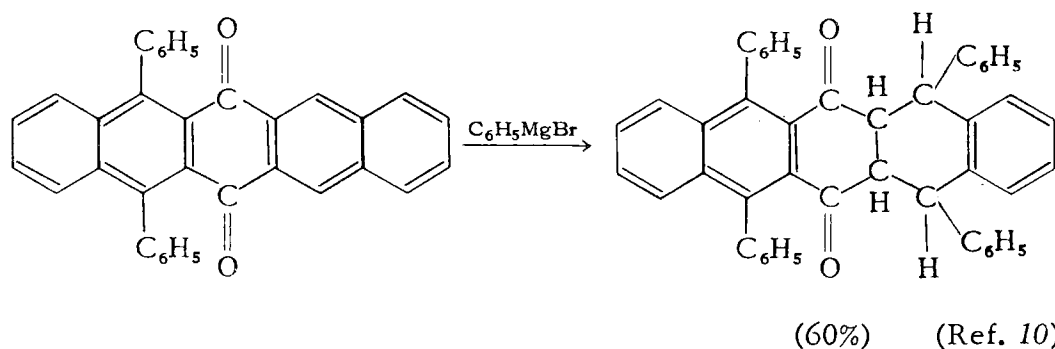


⁷Dufraisse and Horclois, *Bull. soc. chim.*, [5], 3, 1894-905 (1936).

⁸Smith and Hoehn, *J. Am. Chem. Soc.*, 61, 2619-24 (1939).

⁹Crawford, *J. Am. Chem. Soc.*, 63, 1070-3 (1941).

¹⁰Allen and Bell, *J. Am. Chem. Soc.*, 64, 1253-60 (1942).



With a few exceptions the quinones react with Grignard reagents to give only small percentage yields of readily isolable and identifiable products. In most cases the major portion of the reaction product consists of a refractory oil, or tar, or both. Consequently the side-reactions in general have been but little studied.

Reductions of addition products of reactions of quinones with non-reducing Grignard reagents have been reported by Bamberger and Blangey,¹¹ by Barnett *et al.*,¹² and by Allen and Bell.¹³ Allen and Bell maintain, despite the statement of Barnett *et al.* to the contrary, that such reductions take place only in the presence of metallic magnesium. In view of the supplementary evidence on the Grignard reductions of aldehydes and ketones (see Magnesium Halide Reduction, Chapter VI), of the fact that Allen and Bell, as well as others, have found suspended magnesium which has passed through a glass-wool plug capable of effecting such reductions, and of the fact that Barnett *et al.* describe no special precautions taken to free their Grignard reagents of residual magnesium, it appears fairly certain that these reductions are of the Gomberg (*i.e.*, magnesium halide) type.

The results of some experiments by Allen and Bell on 5,12-diphenyl-5,12-dihydro-5,12-naphthacenediol, one of the primary products of the reaction of phenylmagnesium bromide with 5,12-naphthacenequinone (Dufraisse and Horclois;¹⁴ Allen and Bell, *loc. cit.*¹³) are recorded in Table VII-I.

TABLE VII-I

PRODUCTS OF THE TREATMENT OF 5,12-DIPHENYL-5,12-DIHYDRO-5,12-NAPHTHACENEDIOL WITH VARIOUS REAGENTS

Reagent	Recovered diol (%)	5,12-Diphenylnaphthacene* (%)
C ₆ H ₅ MgBr	80	0
Mg	80	0
C ₆ H ₅ MgBr + Mg	0	65
Mg + MgBr ₂	0	73

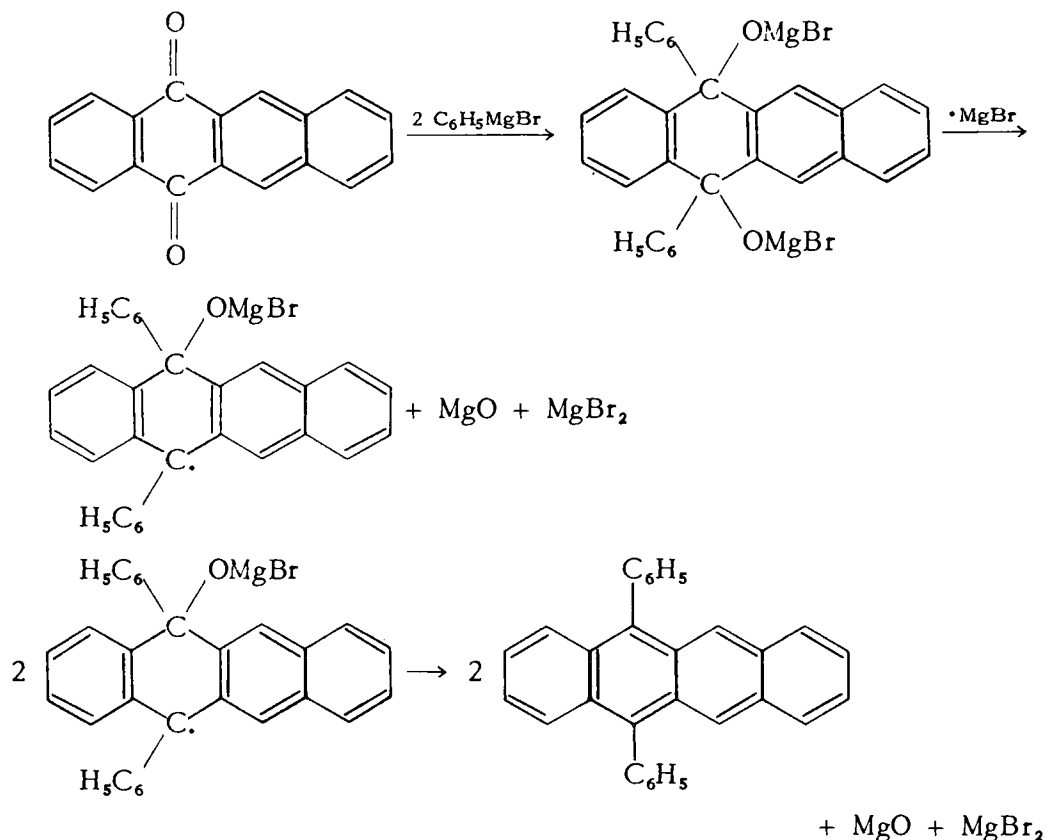
¹¹Bamberger and Blangey, *Ann.*, 384, 272-322 (1911).

¹²Barnett, Cook, and Wiltshire, *J. Chem. Soc.*, 1927, 1724-32.

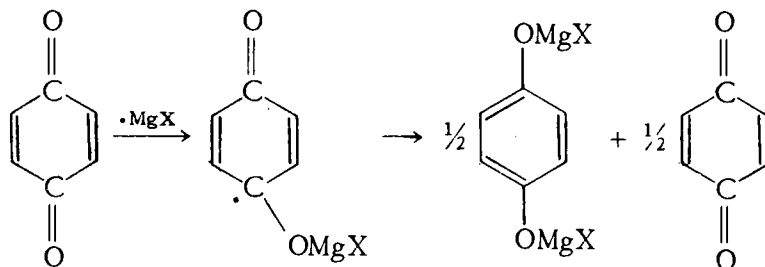
¹³Allen and Bell, *J. Am. Chem. Soc.*, 62, 2408-12 (1940).

¹⁴Dufraisse and Horclois, *Bull. soc. chim.*, [5], 3, 1894-905 (1936).

The mechanism of these reductions has not been studied, but it would appear a reasonable assumption that it is probably related to that of pinacol formation. The following reaction scheme is offered speculatively, with the reservation that the order of the reaction steps need not necessarily be that implied.



A similar reaction mechanism would account for the reduction of the quinones themselves, as reported by Schmidlin *et al.*¹⁵ (benzoquinone \rightarrow quinhydrone), Worrall and Cohen¹⁶ (benzoquinone \rightarrow hydroquinone), Smith and Crawford¹⁷ (duroquinone \rightarrow durohydroquinone), and Bamberger and Blangey (*loc. cit.*¹¹) (toluquinone \rightarrow toluhydroquinone).

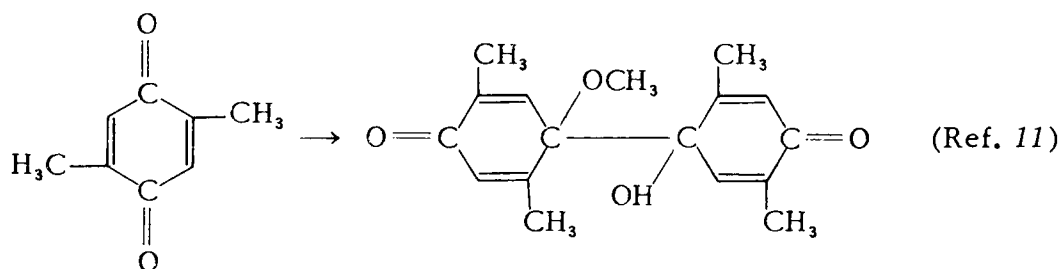
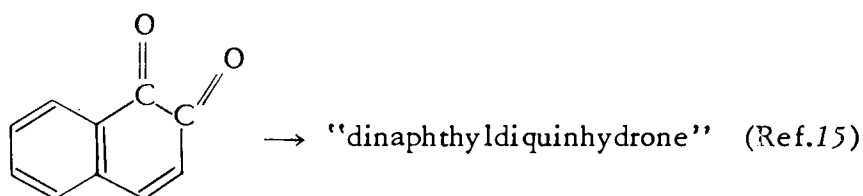


¹⁵Schmidlin, Wohl, and Thommen, *Ber.*, 43, 1298-1303 (1910).

¹⁶Worrall and Cohen, *J. Am. Chem. Soc.*, 58, 533 (1936).

¹⁷Smith and Crawford, *J. Am. Chem. Soc.*, 50, 869-83 (1928).

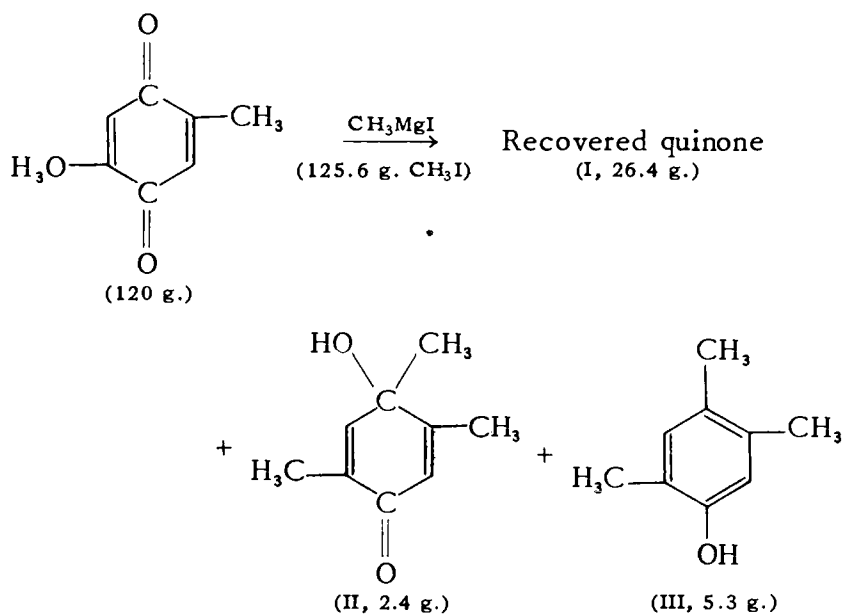
If any of the intermediate free radicals so formed proved capable of coupling rather than disproportionating, bimolecular reduction products such as those reported by Schmidlin *et al.* (*loc. cit.*¹⁵) and Bamberger and Blangey (*loc. cit.*¹¹) could be expected.

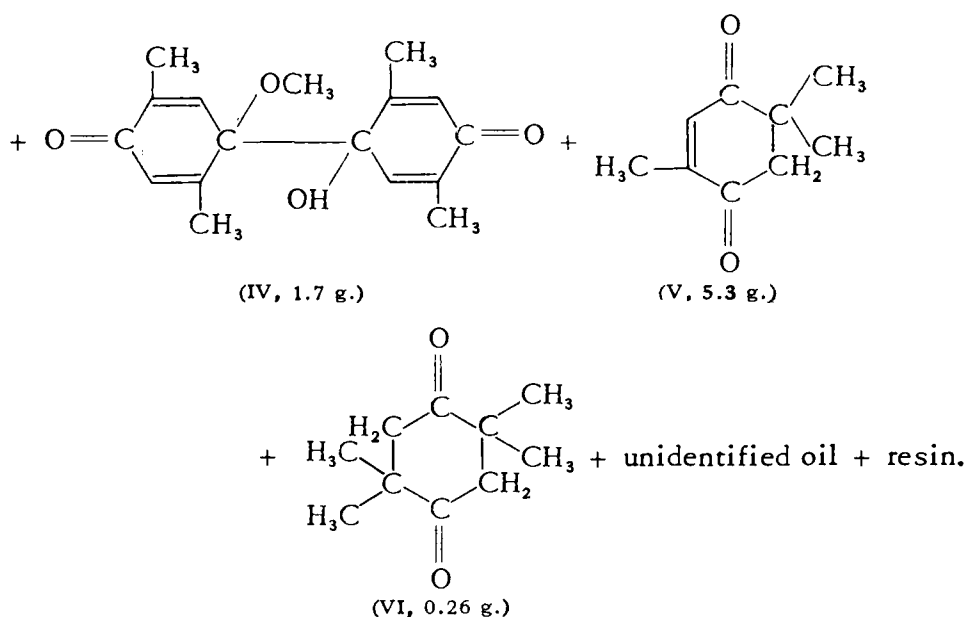


The methoxyl group in the Bamberger and Blangey product is, of course, not the result of a species of reverse Grignard reagent addition (as they suggest) but of a variety of Williamson etherification fairly well known as a side-reaction in ketone-Grignard reagent reactions.

The possibility of oxidation-reduction reactions among the various products of quinone-Grignard reagent interaction or between products and the quinone themselves is, of course, not excluded.

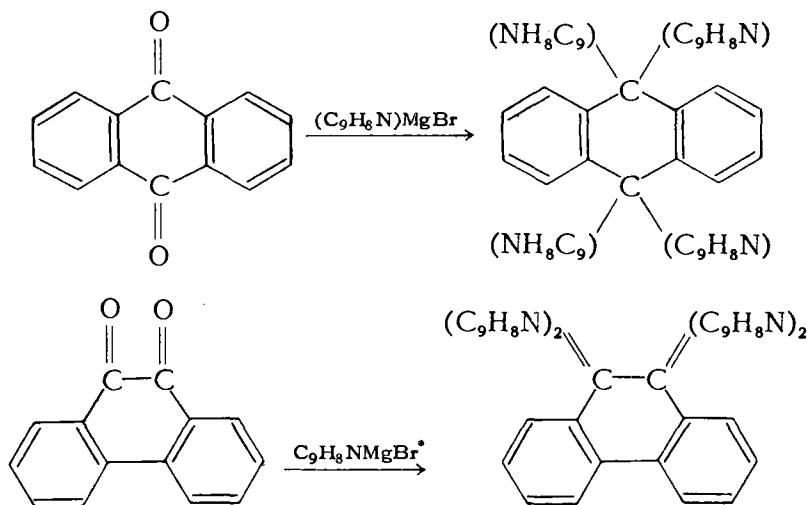
The reaction of phlorone with methylmagnesium iodide may be cited as an example of the few that have been studied in some detail (Bamberger and Blangey, *loc. cit.*¹¹).





When two equivalents of methylmagnesium iodide were used no pseudo-cumoquinol (II) was isolated, but a small amount of prehnitol (2,3,4,5-tetramethylphenol) was found.

Two reactions described by Mingoia,¹⁸ namely, those of 3-methylindolylmagnesium bromide with anthraquinone and 9,10-phenanthrenequinone, await satisfactory elucidation.*



Other reactions of quinones with Grignard reagents are summarized in Table VII-II.

¹⁸Mingoia, *Gazz. chim. ital.*, 56, 446-50 (1926); 58, 673-9 (1929); *Chem. Abstr.*, 21, 242 (1927); 23, 3465 (1929).

*In the abstract available no adequate proof of structure of the products reported is described. Under the circumstances it seems wisest to forego speculative discussion.

TABLE VII-II

REACTIONS OF GRIGNARD REAGENTS WITH QUINONES

<u>Quinone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₄O₂			
o-Quinone	(C ₆ H ₅) ₃ CMgCl	[(C ₆ H ₅) ₃ C] ₂ O ₂ (0.11 g.); black C ₆ H ₆ -insoluble powder	42
Quinone (0.4 mole)	4-C ₆ H ₅ C ₆ H ₄ MgBr (0.1 mole C ₁₂ H ₉ Br)	(4-C ₆ H ₅ C ₆ H ₄ —) ₂ ; (C ₆ H ₅ —) ₂ ; hydroquinone; unidentified oily products; tar.	51
Quinone (10 g.)	(C ₆ H ₅) ₃ CMgCl (20 g. C ₁₉ H ₁₅ Cl)	1,4-[(C ₆ H ₅) ₃ CO] ₂ C ₆ H ₄ (6 g.); quinhydrone	42
C₇H₆O₂			
p-Toluquinone	CH ₃ MgI	3,4-Xyloquinol; p-toluhydroquinone; p-xyloquinone; p-xylohydroquinone; oil; resin	12,11
"Toluquinone" (9.2 g.)	(C ₆ H ₅) ₃ CMgCl (14.0 g. C ₁₉ H ₁₅ Cl)	[(C ₆ H ₅) ₃ C] ₂ O ₂ (0.01 g.); (C ₆ H ₅) ₃ COH; "toluquinhydrone"	42
C₈H₈O₂			
Phlorone (120.0 g.)	CH ₃ MgI (125.6 g. CH ₃ I)	Recovered quinone (26.4 g.); pseudocumoquinol (2,4,5-trimethyl-4-hydroxy-2,5-cyclohexadien-1-one) (2.4 g.); pseudocumenol (2,4,5-trimethylphenol) (5.3 g.); 1-hydroxy-1'-methoxy-1,1'-bis(2,5-dimethyl-4-oxo-2,5-cyclohexadienyl) (1.7 g.); dihydrotrimethylquinone (5.3 g.); 2,2,5,5-tetramethylcyclohexane-1,4-dione (0.26 g.); unidentified oil; resin	12,11
Phlorone (285 g.)	CH ₃ MgI (298 g. CH ₃ I)	Recovered quinone (66.7 g.); pseudocumenol (16.6 g.); dihydrotrimethylquinone (17.9 g.); bi-p-xyloquinol monomethyl ether (3.2 g.); prehnitol (2.1 g.); 2,2,5,5-tetramethylcyclohexane-1,4-dione (0.5 g.); oil (7.3 g.); resin	12,11

TABLE VII-II (Continued)

<u>Quinone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₆O₂			
1,2-Naphthoquinone	C ₆ H ₅ MgBr	C ₁₆ H ₁₀ O ₂	26
1,2-Naphthoquinone	(C ₆ H ₅) ₃ CMgCl	[(C ₆ H ₅) ₃ C] ₂ O ₂ (0.8 g.); (C ₆ H ₅) ₂ CH (5.2 g.); "dinaphthyldiquinhydrone" (7.7 g.)	42
1,4-Naphthoquinone (20 g.)	C ₆ H ₅ MgBr (99 g. C ₆ H ₅ Br)	3,4-Diphenyl-4-hydroxy-3,4-dihydro-1(2H)-naphthalenone (8.1 g.)	47,26,27
1,4-Naphthoquinone	(C ₆ H ₅) ₃ CMgCl	[(C ₆ H ₅) ₃ C] ₂ O ₂ (1.0 g.); "α-hydronaphthoquinone" (0.3 g.)	42
C₁₀H₁₂O₂			
Duroquinone	C ₆ H ₅ MgBr (1 equiv.)	2,3,5,6-Tetramethyl-4-hydroxy-4-phenyl-2,5-cyclohexadien-1-one; 2,3,5,6-tetramethyl-4-hydroxy-6-phenyl-2,4-cyclohexadien-1-one; 2,3,5,6-tetramethyl-6-phenyl-2-cyclohexene-1,4-dione; hydroduroquinone; biphenyl; oil.	46
Duroquinone	C ₆ H ₅ MgBr (4 equiv.)	2,3,5,6-Tetramethyl-4-hydroxy-6-phenyl-2,4-cyclohexadien-1-one; 2,3,5,6-tetramethyl-3,6-diphenyl-1,4-cyclohexadiene-1,4-diol; hydroduroquinone; biphenyl; oil.	46
C₁₁H₈O₂			
2-Methyl-1,4-naphthoquinone	C ₆ H ₅ MgBr	2-Methyl-3,4-diphenyl-3,4-dihydro-1,4-naphthalenediol (5-12.2%); 2-methyl-1,2-diphenyl-1,2-dihydro-1,4-naphthalenediol	20
C₁₁H₈O₃			
2-Methoxy-1,4-naphthoquinone (30 g.)	C ₆ H ₅ MgBr (157 g. C ₆ H ₅ Br)	1-Hydroxy-1,4-diphenyl-2(1H)-naphthalenone (ca. 15 g.)	48
C₁₂H₆O₂			
Acenaphthenequinone	C ₆ H ₅ MgBr	1,2-Diphenyl-1,2-acenaphthenediol	1

TABLE VII-II (Continued)

<u>Quinone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₁₀O₂			
2,3-Dimethyl-1,4-naphthoquinone	C ₆ H ₅ MgBr	1,2-Diphenyl-2,3-dimethyl-1,2-dihydro-1,4-naphthalenediol (chief solid product); 1,4-diphenyl-2,3-dimethyl-1,4-naphthalenediol; 2,3-dimethyl-4-hydroxy-4-phenyl-1 (4 <i>H</i>)-naphthalenone; reduction products; dehydration products	18,19
C₁₄H₆O₂Cl₂			
1,4-Dichloroanthraquinone (5.54 g.)	C ₆ H ₅ MgBr (2.92 g. Mg)	1,4-Dichloro-9,10-diphenyl-9,10-dihydro-9,10-anthradiol (3.4 g.)	25
1,5-Dichloroanthraquinone (12 g.)	C ₆ H ₅ MgBr (4 equiv.)	1,5-Dichloro-9,10-diphenyl-9,10-dihydro-9,10-anthradiol (5 g.); 1,5-dichloroanthraquinone*	13
1,5-Dichloroanthraquinone (5.54 g.)	C ₆ H ₅ MgBr (8.4 g. C ₆ H ₅ Br)	1,5-Dichloro-9,10-diphenyl-9,10-dihydro-9,10-anthradiol (3.1 g.)	25
C₁₄H₇O₂Br			
2-Bromoanthraquinone (78 g.)	C ₆ H ₅ MgBr (120 g. C ₆ H ₅ Br)	2-Bromo-9,10-diphenyl-9,10-dihydro-9,10-anthradiol	34
C₁₄H₇O₂Cl			
1-Chloroanthraquinone	C ₆ H ₅ MgBr (4 equiv.)	1-Chloro-9,10-diphenyl-9,10-dihydro-9,10-anthradiol; 1-chloro-9,10-diphenylanthracene	13
1-Chloroanthraquinone	C ₆ H ₅ MgBr	1-Chloro-9,10-diphenyl-9,10-dihydro-9,10-anthradiol (83%)	2
2-Chloroanthraquinone	C ₆ H ₅ MgBr	2-Chloro-9,10-diphenyl-9,10-dihydro-9,10-anthradiol (90%)	2
2-Chloroanthraquinone	C ₆ H ₅ MgBr	2-Chloro-9,10-diphenyl-9,10-dihydro-9,10-anthradiol	13,34
C₁₄H₈O₂			
Anthraquinone (208 g.)	CH ₃ MgBr (0.5 mole)	10-Hydroxy-10-methyl-9-anthrone (52 g.)	36

* Attributed to atmospheric oxidation of the anthraquinol.

TABLE VII-II (Continued)

Quinone	RMgX	Product(s)	Ref.
C₁₄H₈O₂ (<i>cont.</i>)			
Anthraquinone	CH ₃ MgI (1 equiv.)	9,10-Dimethyl-9,10-dihydro-9,10-anthradiol	29
Anthraquinone (140 g.)	C ₂ H ₅ MgBr (65 g. C ₂ H ₅ Br)	10-Hydroxy-10-ethyl-9-anthrone (65 g., crude)	38
Anthraquinone	C ₂ H ₅ MgBr	9,10-Diethyl-9,10-dihydro-9,10-anthradiol; yellow rhombic plates, m. 161° [9-(9-ethyl-10-ethylidene-9,10-dihydro) anthryl ether (?)]; yellow prisms, m. 226° [C ₃₆ H ₃₄ O (?)]	16
Anthraquinone	2-Furyl-MgBr	9,10-Difuryl-9,10-dihydro-9,10-anthradiol	24
Anthraquinone (10.4 g.)	Pyrrol-MgBr (6.7 g. pyrrole)	9,10-Dipyrrolenyl-9,10-dihydroanthracene	39
Anthraquinone (150 g.)	<i>n</i> -C ₄ H ₉ MgBr (0.5 mole)	10-Hydroxy-10- <i>n</i> -butyl-9-anthrone (66 g.)	37
Anthraquinone	<i>i</i> -C ₅ H ₁₁ MgBr (25 g. C ₅ H ₁₁ Br)	10-Hydroxy-10-isoamyl-9-anthrone	37
Anthraquinone (25 g.)	4-BrC ₆ H ₄ MgI (90 g. C ₆ H ₄ IBr)	9,10-Di- <i>p</i> -bromophenyl-9,10-dihydro-9,10-anthradiol	34
Anthraquinone (30 g.)	4-ClC ₆ H ₄ MgI (95 g. C ₆ H ₄ ICl)	9,10-Di- <i>p</i> -chlorophenyl-9,10-dihydro-9,10-anthradiol	34
Anthraquinone	C ₆ H ₅ MgBr (1 equiv.)	10-Hydroxy-10-phenyl-9-anthrone; 9,10-diphenyl-9,10-dihydro-9,10-anthradiol (10%)	32
Anthraquinone	C ₆ H ₅ MgBr	9,10-Diphenyl-9,10-dihydro-9,10-anthradiol (34%); unchanged anthraquinone	34
Anthraquinone	C ₆ H ₅ MgBr	9,10-Diphenyl-9,10-dihydro-9,10-anthradiol (50%); 9,10-diphenyl-anthracene	13
Anthraquinone (60 g.)	C ₆ H ₅ MgBr (30 g. Mg)	9,10-Diphenyl-9,10-dihydro-9,10-anthradiol (55%)	22
Anthraquinone (large excess)	C ₆ H ₅ CH ₂ MgCl	9,10-Dibenzyl-9,10-dihydro-9,10-anthradiol (poor yield); 10-hydroxy-10-benzyl-9-anthrone	41

TABLE VII-II (Continued)

<u>Quinone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₈O₂ (cont.)			
Anthraquinone (72 g.)	C ₆ H ₅ CH ₂ Cl (64 g.) + Mg (12.5 g.)	10-Hydroxy-10-benzyl-9-anthrone (18-25 g.); recovered anthrone (15-20 g.)	41
Anthraquinone (45.5 g.)	4-CH ₃ C ₆ H ₄ MgI (100 g. C ₇ H ₇ I)	9,10-Di- <i>p</i> -tolyl-9,10-dihydro-9,10-anthradiol (18%)	34
Anthraquinone	2-CH ₃ OC ₆ H ₄ MgBr	9,10-Di- <i>o</i> -anisyl-9,10-dihydro-9,10-anthradiol.	31
Anthraquinone (40 g.)	4-CH ₃ OC ₆ H ₄ MgBr (93.5 g. C ₇ H ₇ BrO)	9,10-Di- <i>p</i> -anisyl-9,10-dihydro-9,10-anthradiol (31 g.)	34, 13, 31
Anthraquinone (40 g.)	4-CH ₃ OC ₆ H ₄ MgI (23.4 g. C ₇ H ₇ IO)	10-Hydroxy-10- <i>p</i> -anisyl-9-anthrone	14
Anthraquinone	C ₆ H ₅ C≡CMgBr	9,10-Di(phenylethynyl)-9,10-dihydro-9,10-anthradiol	23
Anthraquinone (5.2 g.)	2-Methylindolyl-MgBr (13.0 g. 2-methylindole)	9,9,10,10-Tetra-(2-methyl-3-indolyl)-9,10-dihydroanthracene	39
Anthraquinone	1-C ₁₀ H ₇ MgBr	9,10-Di- α -naphthyl-9,10-dihydro-9,10-anthradiol; 10-hydroxy-10- α -naphthyl-9-anthrone.	28
Anthraquinone (5.8 g.)	2-C ₆ H ₅ C ₆ H ₄ MgI (15.6 g. C ₁₂ H ₉ I)	(C ₆ H ₅ —) ₂ (3.7 g.); recovered quinone; 9,10-di- <i>o</i> -biphenyl-9,10-dihydro-9,10-anthradiol (3.6 g., 25%)	17
Anthraquinone	2-C ₆ H ₅ OC ₆ H ₄ MgI	9,10-Di- <i>o</i> -phenoxyphenyl-9,10-dihydro-9,10-anthradiol (47%)	17
9,10-Phenanthrene-quinone (15 g.)	CH ₃ MgI (30 g. CH ₃ I)	9,10-Dimethyl-9,10-dihydro-9,10-phenanthrenediol (60%)	52
9,10-Phenanthrene-quinone (15 g.)	C ₂ H ₅ MgBr (25 g. C ₂ H ₅ Br)	9,10-Diethyl-9,10-dihydro-9,10-phenanthrenediol (<i>ca.</i> 40%)	52
9,10-Phenanthrene-quinone (15 g.)	C ₂ H ₅ MgI (33 g. C ₂ H ₅ I)	9,10-Diethyl-9,10-dihydro-9,10-phenanthrenediol (<i>ca.</i> 40%)	52
9,10-Phenanthrene-quinone (10 g.)	<i>n</i> -C ₃ H ₇ MgBr (21 g. C ₃ H ₇ Br)	9,10-Di- <i>n</i> -propyl-9,10-dihydro-9,10-phenanthrenediol (60-70%)	52
9,10-Phenanthrene-quinone (5.2 g.)	Pyrryl-MgBr (3.4 g. pyrrole)	9,10-Dipyrrolenyl-9,10-dihydrophenanthrene	40

TABLE VII-II (Continued)

<u>Quinone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₈O₂ (cont.)			
9,10-Phenanthrene-quinone (10.4 g.)	4-ClC ₆ H ₄ MgBr (0.2 mole C ₆ H ₄ BrCl)	9,10-Di- <i>p</i> -chlorophenyl-9,10-dihydro-9,10-phenanthrenediol (44%)	9
9,10-Phenanthrene-quinone (10.4 g.)	4-FC ₆ H ₄ MgBr (0.2 mole C ₆ H ₄ BrF)	9,10-Di- <i>p</i> -fluorophenyl-9,10-dihydro-9,10-phenanthrenediol (30%).	9
9,10-Phenanthrene-quinone (20 g.)	C ₆ H ₅ MgBr	9,10-Diphenyl-9,10-dihydro-9,10-phenanthrenediol (25 g.)	1
9,10-Phenanthrene-quinone	C ₆ H ₅ MgI	9,10-Diphenyl-9,10-dihydro-9,10-phenanthrenediol	50
9,10-Phenanthrene-quinone	C ₆ H ₅ CH ₂ MgCl (4 equiv.)	9,10-Dibenzyl-9,10-dihydro-9,10-phenanthrenediol (80-90%)	52
9,10-Phenanthrene-quinone	2-CH ₃ C ₆ H ₄ MgBr	9,10-Di- <i>o</i> -tolyl-9,10-dihydro-9,10-phenanthrenediol (51%)	35
9,10-Phenanthrene-quinone (10.4 g.)	3-CH ₃ C ₆ H ₄ MgBr (0.2 mole C ₇ H ₇ Br)	9,10-Di- <i>m</i> -tolyl-9,10-dihydro-9,10-phenanthrenediol (40%)	9,35
9,10-Phenanthrene-quinone (17 g.)	4-CH ₃ C ₆ H ₄ MgBr (42 g. C ₇ H ₇ Br)	9,10-Di- <i>p</i> -tolyl-9,10-dihydro-9,10-phenanthrenediol (57%)	5,35
9,10-Phenanthrene-quinone	2-CH ₃ OC ₆ H ₄ MgBr	9,10-Di- <i>o</i> -anisyl-9,10-dihydro-9,10-phenanthrenediol (43%)	35
9,10-Phenanthrene-quinone	3-CH ₃ OC ₆ H ₄ MgBr	9,10-Di- <i>m</i> -anisyl-9,10-dihydro-9,10-phenanthrenediol (48%)	35
9,10-Phenanthrene-quinone (17 g.)	4-CH ₃ OC ₆ H ₄ MgBr (46 g. C ₇ H ₇ BrO)	9,10-Di- <i>p</i> -anisyl-9,10-dihydro-9,10-phenanthrenediol (47%)	35,5
9,10-Phenanthrene-quinone	3,4-(CH ₃) ₂ C ₆ H ₃ MgBr	9,10-Di-(3,4-dimethylphenyl)-9,10-dihydro-9,10-phenanthrenediol (23%)	35
9,10-Phenanthrene-quinone	2-C ₂ H ₅ OC ₆ H ₄ MgBr	9,10-Di- <i>o</i> -phenetyl-9,10-dihydro-9,10-phenanthrenediol (52%)	35
9,10-Phenanthrene-quinone	3-C ₂ H ₅ OC ₆ H ₄ MgBr	9,10-Di- <i>m</i> -phenetyl-9,10-dihydro-9,10-phenanthrenediol (39%)	35

TABLE VII-II (Continued)

<u>Quinone</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₄H₆O₂ (cont.)			
9,10-Phenanthrene-quinone (10.4 g.)	4-C ₂ H ₅ OC ₆ H ₄ MgBr (0.2 mole C ₈ H ₉ BrO)	9,10-Di- <i>p</i> -phenetyl-9,10-dihydro-9,10-phenanthrenediol (33%)	9,35
9,10-Phenanthrene-quinone (2.6 g.)	2-Methylindolyl-MgBr (6.5 g. 2-methylindole)	9,9,10,10-Tetra-(2-methyl-3-indolyl)-9,10-dihydrophenanthrene	40
9,10-Phenanthrene-quinone (10.4 g.)	1-C ₁₀ H ₇ MgBr (0.2 mole C ₁₀ H ₇ Br)	9,10-Di- α -naphthyl-9,10-dihydro-9,10-phenanthrenediol (31%)	9
9,10-Phenanthrene-quinone (10.4 g.)	4-C ₆ H ₅ C ₆ H ₄ MgBr (0.2 mole C ₁₂ H ₉ Br)	9,10-Di- <i>p</i> -biphenyl-9,10-dihydro-9,10-phenanthrenediol (65%)	9
C₁₅H₁₀O₂			
2-Methylanthraquinone	C ₆ H ₅ MgBr (excess)	2-Methyl-9,10-diphenyl-9,10-dihydro-9,10-anthradiol (95%); 2-methyl-10-hydroxy-10-phenyl-9-anthrone	28
2-Methylanthraquinone	C ₆ H ₅ MgBr	2-Methyl-9,10-diphenyl-9,10-dihydro-9,10-anthradiol (86%)	2
2-Methylanthraquinone	4-CH ₃ C ₆ H ₄ MgBr (excess)	2-Methyl-9,10-di- <i>p</i> -tolyl-9,10-dihydro-9,10-anthradiol ("excellent yield")	30
2-Methylanthraquinone	4-CH ₃ OC ₆ H ₄ MgBr	2-Methyl-9,10-di- <i>p</i> -anisyl-9,10-dihydro-9,10-anthradiol	31
C₁₅H₁₀O₃			
2-Methoxyanthraquinone (4.7 g.)	4-CH ₃ OC ₆ H ₄ MgI (5.8 g. C ₇ H ₇ IO)	2-Methoxy-10-hydroxy-10- <i>p</i> -anisyl-9-anthrone (2.3 g.)	14
C₁₆H₆O₂S			
5,6-Benzo-4,9-thiophenanthrene-quinone (0.95 g.)	CH ₃ MgI (1 g. Mg)	4,9-Dimethyl-5,6-benzothiophenanthrene (0.7 g.)*	53

*After treatment with HI and reduction with SnCl₂.

TABLE VII-II (Continued)

<u>Quinone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₈O₂S (<i>cont.</i>)			
7,8-Benzo-4,9-thiophenanthrene-quinone	CH ₃ Mgl	4,9-Dimethyl-7,8-benzothiophenanthrene*	53
C₁₆H₁₂O₂			
1,2-Dimethylantraquinone (7.1 g.)	CH ₃ Mgl (8.4 ml. CH ₃ I)	1,2,9,10-Tetramethyl-9,10-anthradiol (3.2 g.)	10
1,4-Dimethylantraquinone (5.9 g.)	C ₆ H ₅ MgBr (3.95 g. C ₆ H ₅ Br)	Recovered quinone (5.5 g.); 1,4-dimethyl-10-hydroxy-10-phenyl-9-anthrone (0.6 g.)	43
1,4-Dimethylantraquinone 5.9 g.)	C ₆ H ₅ MgBr (40 g., <i>ca.</i> 10 equiv., C ₆ H ₅ Br)	1,4-Dimethyl-9,10-diphenyl-9,10-dihydro-9,10-anthradiol (55%)	43
2,3-Dimethylantraquinone	C ₆ H ₅ MgBr	2,3-Dimethyl-9,10-diphenyl-9,10-dihydro-9,10-anthradiol (77%)	2
C₁₆H₁₂O₄			
1,2-Dimethoxyanthraquinone	C ₂ H ₅ Mgl (1.5 equiv.)	1,2-Dimethoxy-10-hydroxy-10-ethyl-9-anthrone (<i>ca.</i> 22%)	45
1,2-Dimethoxyanthraquinone	C ₂ H ₅ Mgl (2.5 equiv.)	1,2-Dimethoxy-9,10-diethyl-9,10-dihydro-9,10-anthradiol (<i>ca.</i> 18%); 1,2-dimethoxy-10-hydroxy-10-ethyl-9-anthrone; recovered quinone	45
C₁₆H₁₂O₂			
Benz[<i>a</i>]anthracene-7,12-dione (5.16 g.)	<i>n</i> -C ₃ H ₇ MgBr	7,12-Di- <i>n</i> -propyl-7,12-dihydrobenz[<i>a</i>]anthracene-7,12-diol (isolated as the dimethyl ether, 3.9 g.)	8,6
Benz[<i>a</i>]anthracene-7,12-dione	C ₆ H ₅ MgBr	7,12-Diphenyl-7,12-dihydrobenz[<i>a</i>]anthracene-7,12-diol (78%) [†]	2

* After treatment with HBr-HI and reduction with SnCl₂.[†]Add'n of *n*-Bu₂O-quinone sol'n to Mg-free Et₂O-G.r. sol'n; 3 hrs. stirring at 100° with dist'n of Et₂O.

TABLE VII-II (Continued)

<u>Quinone</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₈H₁₂O₂ (cont.)			
Benz[<i>a</i>] anthracene-7,12-dione	C ₆ H ₅ MgBr	7,12-Diphenyl-7,12-dihydrobenz[<i>a</i>] anthracene-7,12-diol (70%)*	2
5,12-Naphthacenequinone	C ₆ H ₅ MgBr (6 equiv.)	6,11-Diphenyl-5a,6,11,11a-tetrahydro-5,12-naphthacenequinone (20.4%); 5,12-diphenylnaphthacene (25.0%); <i>no diol</i> †	4,2
5,12-Naphthacenequinone	C ₆ H ₅ MgBr	5,12-Diphenyl-5,12-dihydro-5,12-naphthacenediol (58%); 6,11-diphenyl-5a,6,11,11a-tetrahydro-5,12-naphthacenequinone (6%)‡	2
5,12-Naphthacenequinone	C ₆ H ₅ MgBr + Mg	5,12-Diphenyl-5,12-dihydro-5,12-naphthacenediol (27%); 6,11-diphenyl-5a,6,11,11a-tetrahydronaphthacenequinone (15%); 5,12-diphenylnaphthacene (12%)§	2
5,12-Naphthacenequinone	C ₆ H ₅ MgBr	5,12-Diphenyl-5,12-dihydro-5,12-naphthacenediol (40%); 6,11-diphenyl-5a,6,11,11a-tetrahydronaphthacenequinone (15%)	2
5,12-Naphthacenequinone (0.4 g.)	C ₆ H ₅ MgBr (2 g. C ₆ H ₅ Br)	5,12-Diphenyl-5,12-dihydro-5,12-naphthacenediol (0.32 g., 50%)	21
C₁₈H₁₄O₂			
1,2,3,4-Tetrahydrobenz[<i>a</i>] anthracene-7,12-dione	C ₆ H ₅ MgBr	7,12-Diphenyl-1,2,3,4,7,12-hexahydrobenz[<i>a</i>] anthracene-7,12-diol (70%)	2
C₁₈H₁₆O₂			
7,8,9,10-Tetrahydronaphthacenequinone	C ₆ H ₅ MgBr	5,12-Diphenyl-5,7,8,9,10,12-hexahydro-5,12-naphthacenediol (60%)	21
Retenequinone†	C ₆ H ₅ MgBr	9,10-Diphenyl-9,10-dihydro-9,10-retenediol	33

*Add'n of C₆H₆-quinone sol'n to Mg-free Et₂O-G.r. sol'n; 3 hrs. stirring on steam bath with dist'n of Et₂O.

†Portionwise add'n of quinone to filtered Et₂O-*n*-Bu₂O-G.r. sol'n; 2 hrs. stirring at 85-90°.

‡Add'n of C₇H₈-quinone sol'n to Mg-free Et₂O-G.r. sol'n; 3 hrs. stirring at 100° with dist'n of Et₂O.

§As above, save for presence of traces of Mg.

¶1-Methyl-7-isopropyl-9,10-phenanthrenedione.

TABLE VII-II (Continued)

<u>Quinone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₉H₁₂O₂			
8-Methylbenz[<i>a</i>] anthracene-7,12-dione (3.56 g.)	CH ₃ MgI (3.3 ml. CH ₃ I)	7,8,12-Trimethyl-7,12-dihydrobenz[<i>a</i>] anthracene-7,12-diol (3.6 g., 91%)	7
9-Methylbenz[<i>a</i>] anthracene-7,12-dione (7.1 g.)	CH ₃ MgI (6.6 ml. CH ₃ I)	7,9,12-Trimethyl-7,12-dihydrobenz[<i>a</i>] anthracene-7,12-diol (yielding 2.35 g. of the dimethyl ether)	10
C₂₀H₁₂O₂			
1-Phenylanthraquinone	C ₆ H ₅ MgBr (10 equiv.)	1,9,10-Triphenyl-9,10-dihydro-9,10-anthradiol	49
2-Phenylanthraquinone	C ₆ H ₅ MgBr	2,9,10-Triphenyl-9,10-dihydro-9,10-anthradiol (80%)	2
C₂₀H₁₄O₂			
8-Ethylbenz[<i>a</i>] anthracene-7,12-dione (3.75 g.)	CH ₃ MgI (5.0 ml. CH ₃ I)	7,12-Dimethyl-8-ethyl-7,12-dihydrobenz[<i>a</i>] anthracene-7,12-diol (3.54 g.)	8
8,9-Dimethylbenz[<i>a</i>] anthracene-7,12-dione (5.0 g.)	CH ₃ MgI (5.0 ml. CH ₃ I)	7,8,9,12-Tetramethyl-7,12-dihydrobenz[<i>a</i>] anthracene-7,12-diol (2.2 g.)	10
C₂₁H₁₆O₂			
8- <i>n</i> -Propylbenz[<i>a</i>] anthracene-7,12-dione (4.42 g.)	CH ₃ MgI	7,12-Dimethyl-8- <i>n</i> -propyl-7,12-dihydrobenz[<i>a</i>] anthracene-7,12-diol (3.9 g.)	8
C₂₂H₁₀O₄			
5,7,12,14-Pentacene-tetrone	C ₆ H ₅ MgBr	5,7,12,14-Tetraphenyl-5,7,12,14-tetrahydro-5,7,12,14-pentacene-tetrol (76%)	3

TABLE VII-II (Continued)

<u>Quinone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₂H₁₂O₂ 6,13-Pentacenedione	C ₆ H ₅ MgBr	<i>trans</i> -6,13-Diphenyl-6,13-dihydropentacene-6,13-diol (70%); 5,14-diphenyl-5,5a,13a,14-tetrahydro-6,13-pentacenedione (15%)	3
C₂₂H₁₆O₂ 1,2,3,4-Tetrahydro- 6,13-pentacenedione	C ₆ H ₅ MgBr	6,13-Diphenyl-1,2,3,4,6,13-hexahydropentacene (66%)	2
C₂₄H₁₈O₄ 6,13-Diphenyl-5,7,12,- 14-pentacentetrone	C ₆ H ₅ MgBr	5,6,7,12,13,14-Hexaphenyl-5,7,12,14-tetrahydro-5,7,12,14-pentacene-tetrol	3
C₂₆H₁₆O₂ 1,4-Diphenylanthra- quinone (3 g.)	C ₆ H ₅ MgBr (15.6 g. C ₆ H ₅ Br)	1,4,9,10-Tetraphenyl-9,10-dihydro-9,10-anthradiol.	49
2,3-Diphenylanthra- quinone	C ₆ H ₅ MgBr	2,3,9,10-Tetraphenyl-9,10-dihydro-9,10-anthradiol (80%)	2
C₂₈H₁₆O₂ Bianthraquinone	2-ClC ₆ H ₄ MgX	"10,10'-Dihydroxy-10,10'-di(o-chlorophenyl)dianthranene"	44
Bianthraquinone (4 g.)	C ₆ H ₅ MgBr (7.2 g. C ₆ H ₅ Br)	"10,10'-Dihydroxy-10,10'-diphenyldianthranene" (3.6 g., crude)	44
Bianthraquinone	C ₆ H ₅ CH ₂ MgBr	"10,10'-Dihydroxy-10,10'-dibenzilyldianthranene"	44
Bianthraquinone	1-C ₁₀ H ₇ MgX	"10,10'-Dihydroxy-10,10'-di-α-naphthyldianthranene"	44

TABLE VII-II (Continued)

<u>Quinone</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃₀H₂₀O₂			
6,11-Diphenylnaphthacenequinone	C ₆ H ₅ MgBr	No isolable product; 70% quinone recovery	4,2
6,11-Diphenylnaphthacenequinone	C ₆ H ₅ MgBr	5,6,11,12-Tetraphenyl-5,12-dihydro-5,12-naphthacenediol (50%)	2
C₃₄H₂₀O₂			
5,14-Diphenyl-6,13-pentacenedione	C ₆ H ₅ MgBr	Mixture of stereoisomers: 5,7,12,14-tetraphenyl-6a,7,12,12a-tetrahydro-6,13-pentacenedione (60%)	3

REFERENCES FOR TABLE VII-II

- (1) Acree, *Am. Chem. J.*, 33, 180-95 (1905).
- (2) Allen and Bell, *J. Am. Chem. Soc.*, 62, 2408-12 (1940).
- (3) Allen and Bell, *J. Am. Chem. Soc.*, 64, 1253-60 (1942).
- (4) Allen and Gilman, *J. Am. Chem. Soc.*, 58, 937-40 (1936).
- (5) Bachmann, *J. Am. Chem. Soc.*, 54, 1969-74 (1932).
- (6) Bachmann and Bradbury, *J. Org. Chem.*, 2, 175-82 (1937).
- (7) Bachmann and Chemerda, *J. Am. Chem. Soc.*, 60, 1023-6 (1938).
- (8) Bachmann and Chemerda, *J. Am. Chem. Soc.*, 61, 2358-61 (1939).
- (9) Bachmann and Chu, *J. Am. Chem. Soc.*, 57, 1095-8 (1935).
- (10) Badger, Cook, and Goulden, *J. Chem. Soc.*, 1940, 16-8.
- (11) Bamberger and Blangey, *Ber.*, 36, 1625-8 (1903).
- (12) Bamberger and Blangey, *Ann.*, 384, 272-322 (1911).
- (13) Barnett, Cook, and Wiltshire, *J. Chem. Soc.*, 1927, 1724-32.
- (14) Blicke and Weinkauff, *J. Am. Chem. Soc.*, 54, 1460-4 (1932).
- (15) Clarke, *Ber.*, 41, 935-6 (1908).
- (16) Clarke and Carleton, *J. Am. Chem. Soc.*, 33, 1966-73 (1911).
- (17) Clarkson and Gomberg, *J. Am. Chem. Soc.*, 52, 2881-91 (1930).
- (18) Crawford, *J. Am. Chem. Soc.*, 57, 2000-4 (1935).
- (19) Crawford, *J. Am. Chem. Soc.*, 61, 3310-4 (1939).
- (20) Crawford, *J. Am. Chem. Soc.*, 63, 1070-3 (1941).
- (21) Dufraisse and Horclois, *Bull. soc. chim.*, [5], 3, 1894-905 (1936).
- (22) Dufraisse and Le Bras, *Bull. soc. chim.*, [5], 4, 1037-45 (1937).
- (23) Dufraisse, Mathieu, and Rio, *Compt. rend.*, 227, 937-9 (1948); *Chem. Abstr.*, 43, 3401 (1949).
- (24) Etienne and Brisson, *Compt. rend.*, 224, 1775-7 (1947); *Chem. Abstr.*, 42, 1259 (1948).
- (25) Fedorov, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1947, 397-404; *Chem. Abstr.*, 42, 1585 (1948).
- (26) Franssen, *Bull. soc. chim.*, [4], 37, 902-13 (1925).
- (27) Franssen, *Bull. soc. chim.*, [4], 45, 1030-44 (1929).
- (28) Guyot and Staehling, *Bull. soc. chim.*, [3], 33, 1104-21 (1905).
- (29) Guyot and Staehling, *Bull. soc. chim.*, [3], 33, 1144-52 (1905).
- (30) Guyot and Vallette, *Ann. chim.*, [8], 23, 363-97 (1911).
- (31) Haller and Comtesse, *Compt. rend.*, 150, 1290-5 (1910); *Chem. Zentr.*, 1910, II, 218.
- (32) Haller and Guyot, *Compt. rend.*, 138, 1251-4 (1904); *Chem. Zentr.*, 1904, II, 117.
- (33) Heiduschka and Grimm, *Arch. Pharm.*, 248, 89-101 (1909); *Chem. Zentr.*, 1910, I, 1975.
- (34) Jezierski, *Roczniki Chem.*, 19, 307-16 (1939); *Chem. Abstr.*, 34, 3729 (1940).
- (35) Julian, Cole, and Diemer, *J. Am. Chem. Soc.*, 67, 1721-3 (1945).
- (36) Julian, Cole, and Meyer, *J. Am. Chem. Soc.*, 67, 1724-7 (1945).
- (37) Julian, Cole, and Wood, *J. Am. Chem. Soc.*, 57, 2508-13 (1935).
- (38) Mingoia, *Gazz. chim. ital.*, 56, 446-50 (1926); *Chem. Abstr.*, 21, 242 (1927).
- (39) Mingoia, *Gazz. chim. ital.*, 58, 673-9 (1928); *Chem. Abstr.*, 23, 3465 (1929).
- (40) Schmidlin, Wohl, and Thommen, *Ber.*, 43, 1298-303 (1910).
- (41) Scholl and Meyer, *Ann.*, 512, 112-24 (1934).
- (42) Schönberg and Ismail, *J. Chem. Soc.*, 1945, 201-2.
- (43) Sirker, *J. Chem. Soc.*, 107, 1241-7 (1915).
- (44) Smith and Crawford, *J. Am. Chem. Soc.*, 50, 869-83 (1928).
- (45) Smith and Hoehn, *J. Am. Chem. Soc.*, 61, 2619-24 (1939).
- (46) Smith and Hoehn, *J. Am. Chem. Soc.*, 63, 1178-9 (1941).

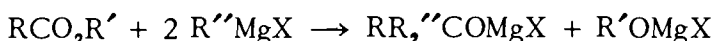
- (47) Weizmann, Bergmann, and Haskelberg, *J. Chem. Soc.*, 1939, 391-7.
- (48) Werner and Grob, *Ber.*, 37, 2887-903 (1904).
- (49) Worrall and Cohen, *J. Am. Chem. Soc.*, 58, 533 (1936).
- (50) Zincke and Tropp, *Ann.*, 362, 242-59 (1908).
- (51) Sandin and Kitchen, *J. Am. Chem. Soc.*, 67, 1305-7 (1945).

CHAPTER VIII

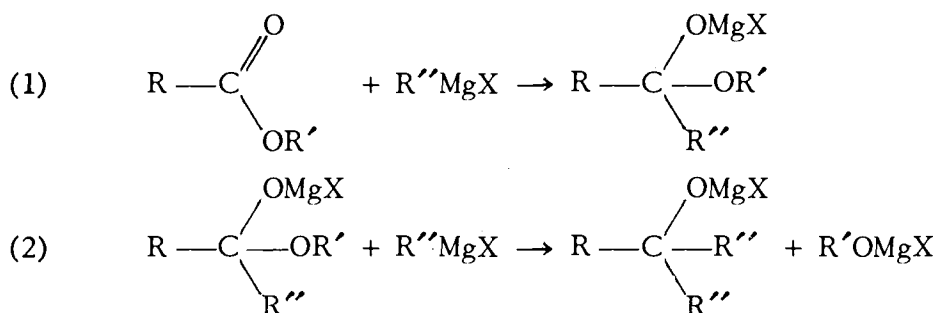
Reactions of Grignard Reagents with Esters and Lactones

"NORMAL" ADDITION TO CARBOXYLIC ESTERS

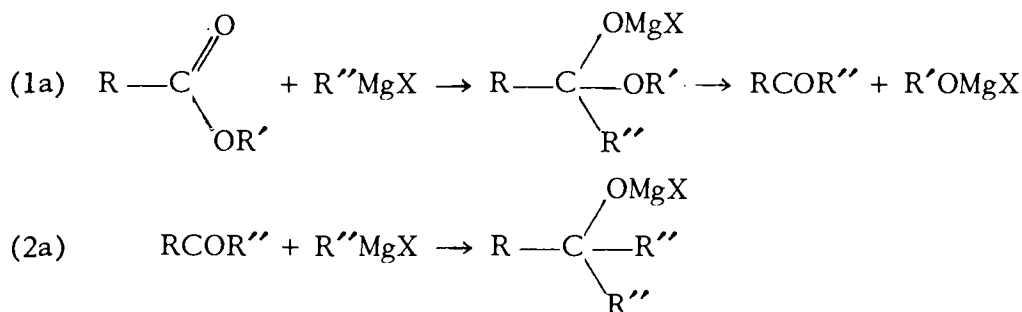
The reaction between a carboxylic ester of the type $\text{RCO}_2\text{R}'$ and a Grignard reagent commonly regarded as the "normal" one is that in which one molecule of the former reacts with two molecules of the latter to form a halomagnesium *t*-alkoxide (a *s*-alkoxide in the special case of a formic ester) and the halomagnesium alkoxide corresponding to the ester alcohol.



Grignard¹ represented the reaction as taking place in two stages:



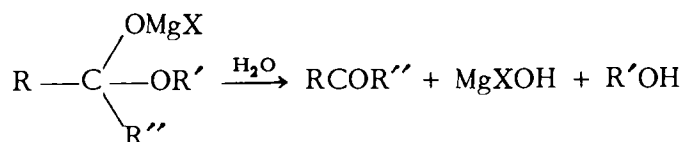
This representation is, of course, satisfactory from a stoichiometric point of view, but there is a reasonable question that it adequately describes the mechanism of the reaction. Equally satisfactory from a stoichiometric standpoint would be the sequence:



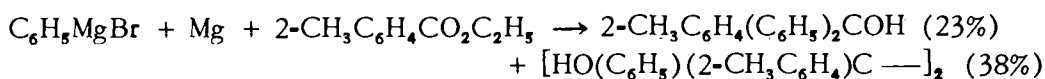
¹Grignard, *Compt. rend.*, 132, 336-8 (1901); *J. Chem. Soc.*, 80, 1, 250 (1901); *Ann. chim.*, [7], 24, 433-90 (1901).

The available evidence upon which to base a choice between the two reaction schemes is inconclusive, but, on the whole, would appear to favor the former except, possibly, in the case of "sterically hindered" esters.

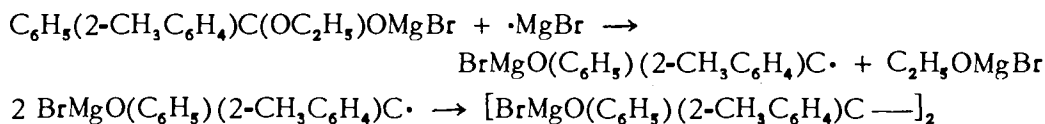
Although it is true that ketones are among the final products of reaction of some esters with some Grignard reagents, it has not been demonstrated that they are present prior to hydrolysis; they may result from the hydrolysis of relatively stable products of the type postulated by Grignard.



Boyd and Hatt² found that, in the presence of free magnesium, phenylmagnesium bromide reacts with ethyl *o*-toluate to form a pinacol as well as a carbinol.

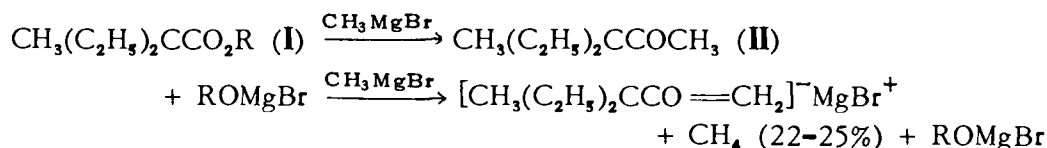


They argue that pinacol formation is evidence of the presence of free ketone, from which the pinacol is derived by a Gomberg (*i.e.*, magnesious halide) reaction. This argument can be conclusive, however, only if the possibility of such a reaction sequence as



is excluded.

Whitmore and Lewis³ found that, when treated with methylmagnesium bromide in the "Grignard machine," the non-enolizable ethyl and butyl esters of α -methyl- α -ethylbutyric acid (I) underwent apparent enolization to the extent of 25 percent and 22 percent, respectively. They attributed this phenomenon to intermediate ketone formation and enolization of the ketone.



It may or may not be significant that under essentially the same conditions 3-methyl-3-ethyl-2-pentanone (II) undergoes 84 percent enolization, or that the ethyl ester of α,α -dimethylbutyric acid (III) shows no apparent enolization, whereas 3,3-dimethyl-2-pentanone (IV) undergoes 14 percent enolization (Whitmore and Lewis, *loc. cit.*³).

²Boyd and Hatt, *J. Chem. Soc.*, 1927, 898-910.

³Whitmore and Lewis, *J. Am. Chem. Soc.*, 64, 2964-6 (1942).

$\text{CH}_3(\text{C}_2\text{H}_5)_2\text{CCO}_2\text{C}_2\text{H}_5$ (IA) $\xrightarrow{2 \text{ CH}_3\text{MgBr}}$ Add'n. (45%); enolization (25%)

$\text{CH}_3(\text{C}_2\text{H}_5)_2\text{CCO}_2\text{-}n\text{-C}_4\text{H}_9$ (IB) $\xrightarrow{2 \text{ CH}_3\text{MgBr}}$ Add'n. (60%); enolization (22%)

$\text{CH}_3(\text{C}_2\text{H}_5)_2\text{CCOCH}_3$ (II) $\xrightarrow{\text{CH}_3\text{MgBr}}$ Add'n. (0%); enolization (84%)

$\text{C}_2\text{H}_5(\text{CH}_3)_2\text{CCO}_2\text{C}_2\text{H}_5$ (III) $\xrightarrow{2 \text{ CH}_3\text{MgBr}}$ Add'n. (100%); enolization (0%)

$\text{C}_2\text{H}_5(\text{CH}_3)_2\text{CCOCH}_3$ (IV) $\xrightarrow{\text{CH}_3\text{MgBr}}$ Add'n. (74%); enolization (14%)

There is, however, at least a strong suggestion (which it would be imprudent to ignore altogether) that the initial reaction product is an intermediate (possibly a hemiketal derivative) which is more susceptible to further Grignard reagent addition, and less susceptible to Grignard reagent enolization, than is the corresponding free ketone.*

The postulate that the initially-formed intermediate is more reactive (with respect to further addition of the Grignard reagent) than is the corresponding ketone would necessarily imply that, in general, the second stage of addition is considerably more rapid than the first, for, although misdirected ingenuity may discover apparent exceptions (notably among the "hindered" ketones), it is generally true that a ketonic function is more reactive (with respect to Grignard reagent addition) than a reasonably comparable ester function. With regard to the more reactive esters, at least, this implication is consistent with experimental observation, for the treatment of one molecular equivalent of ester with one molecular equivalent of Grignard reagent is much more likely to result in the formation of approximately one-half molecular equivalent of tertiary alcohol and the recovery of approximately one-half molecular equivalent of ester than in anything approaching the formation of one molecular equivalent of ketone.

Approaching the point in question from a somewhat different direction, Morton and Peakes⁴ argue that if a free ketone is indeed an intermediate in the Grignard preparation of tertiary alcohols from esters, the yield of tertiary alcohol from the appropriate ketone should be as high as, or higher than, that from the ester. They cite the preparations of 2,2',4,4'-tetramethoxytriphenylmethanol from 2,4-dimethoxyphenylmagnesium iodide and 2,4-dimethoxybenzophenone by Kauffman and Kieser⁵ (37 percent) and from 2,4-dimethoxyphenylmagnesium iodide and methyl benzoate by Lund⁶ (60 percent). They also found that the reaction between phenylmagnesium bromide and methyl 2,4,6-tribromobenzoate yielded 28 percent of the expected carbinol, whereas under the same conditions the same Grignard

*This need not, of course, be construed as a generalization; the relative reactivities of hemiketal derivatives and corresponding ketones with respect to addition and enolization might well vary from case to case.

⁴Morton and Peakes, *J. Am. Chem. Soc.*, 55, 2110-2 (1933).

⁵Kauffman and Kieser, *Ber.*, 45, 2333-7 (1912).

⁶Lund, *J. Am. Chem. Soc.*, 49, 1346-60 (1927).

reagent and the appropriate ketone yielded only traces of carbinol (and quantities of tar).

Ivanoff and Spassoff,^{6,1} on the other hand, although they accept in part the reaction scheme of Grignard, believe that the hemiketal-type intermediate first formed is unstable and decomposes spontaneously to liberate free ketone. In support of this opinion they claim that substantially the same amount of gas is liberated whether an alkyl Grignard reagent is caused to react with an aliphatic ester or with the ketone corresponding to the first stage of ester-Grignard reagent addition. Although the Grignard reagents actually employed are potentially reducing agents, it is assumed, in view of the relatively high yields of ketols isolated from some of the ester reactions, that the gas liberated is essentially an enolization product. A summary of the corroborative data offered is reproduced in Table VIII-I. No explicit statement concerning the basis of calculation employed is made, but percentage of gas liberated would presumably be related, in the case of ketones, to the amount of Grignard reagent consumed, and, in the case of esters, to the second equivalent of Grignard reagent consumed.

TABLE VIII-I

RELATIVE AMOUNTS OF GASES LIBERATED IN THE REACTIONS OF CERTAIN ALKYL MAGNESIUM HALIDES WITH CERTAIN ALIPHATIC ESTERS AND WITH THE RESPECTIVE KETONES CORRESPONDING TO THE FIRST STAGE OF ESTER ADDITION

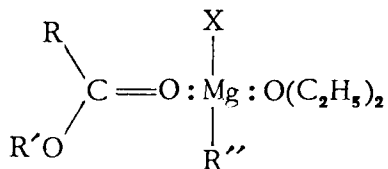
<u>RMgX</u>	<u>Gas Evolution (%)</u>	
	Ester	Ketone
$\text{C}_2\text{H}_5\text{MgBr}$	$\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5$, 1.5	$\text{CH}_3\text{COC}_2\text{H}_5$, 5.9
$n\text{-C}_3\text{H}_7\text{MgBr}$	$\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5$, 5.0	$\text{CH}_3\text{CO-}n\text{-C}_3\text{H}_7$, 10.0
$i\text{-C}_3\text{H}_7\text{MgCl}$	$\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5$, 92.6	$\text{CH}_3\text{CO-}i\text{-C}_3\text{H}_7$, 86.6
$\text{C}_2\text{H}_5\text{MgBr}$	$\text{C}_2\text{H}_5\text{CO}_2\text{C}_2\text{H}_5$, 0.7	$(\text{C}_2\text{H}_5)_2\text{CO}$, 0.9
$i\text{-C}_3\text{H}_7\text{MgCl}$	$\text{C}_2\text{H}_5\text{CO}_2\text{C}_2\text{H}_5$, 72.0	$\text{C}_2\text{H}_5\text{CO-}i\text{-C}_3\text{H}_7$, 70.6

In the opinion of the present authors the evidence offered by Ivanoff and Spassoff is susceptible of at least three interpretations. (1) Ivanoff and Spassoff are correct in their primary premise, and the intermediate resulting from the first stage of carboxylic ester-Grignard reagent addition is, in fact, a free ketone. (2) The stability of the postulated hemiketal-type intermediate varies with the individual case, and further reaction may take place either through the hemiketal derivative itself or through its decomposition product, the free ketone. (3) The true intermediate is indeed the postulated hemiketal derivative, but the choice of reactants by Ivanoff and Spassoff is fortuitously such that in the cases studied the respective relative susceptibilities of the hemiketal derivatives and the corresponding ketones to addition and enolization do not differ markedly.

^{6,1}Ivanoff and Spassoff, *Bull. soc. chim.*, [5], 2, 816-24 (1935).

In the light of all the evidence here outlined, and of a survey of the (rather fragmentary) relevant quantitative data to be gleaned from Tables VI-XVIII and VIII-III, the present authors are inclined to reject interpretation 1 (at least as a general proposition) and to favor interpretation 3 (at least tentatively), without, however, excluding interpretation 2 as a reasonable possibility.

Probable mechanisms of carboxylic ester reactions. Doubtless reaction of any kind is preceded, as in the case of ketones (and, presumably, aldehydes), by Werner complex formation.

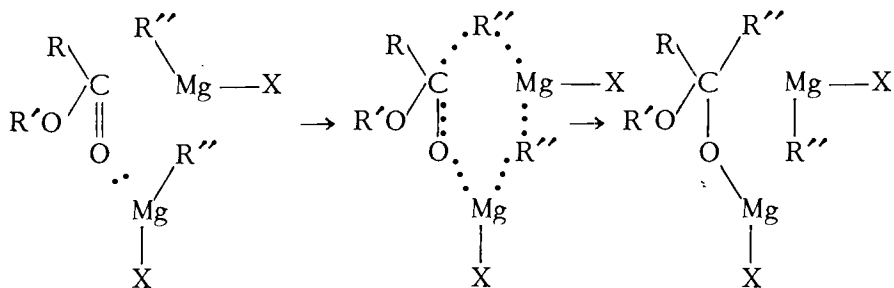


In favorable cases such complexes are isolable. Stadnikoff⁷ found, for example, that when 0.1 mole (23 g.) of benzhydryl acetate is added dropwise to one equivalent of a cooled, agitated ethereal solution of ethylmagnesium iodide a white precipitate is formed. In the experiment described, after twenty minutes of additional cooling and shaking, the precipitate was separated and treated with water, whereupon 21 g. of the original ester was recovered.

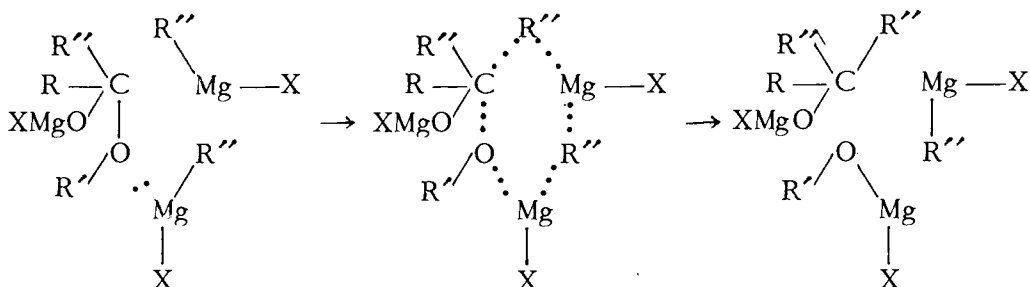
For reasons discussed in connection with the ketone-Grignard reagent complexes (Chapter VI), a complex of the oxonium salt type, as postulated by Stadnikoff (*loc. cit.*⁷), appears highly improbable. Indeed, some of the ("abnormal") reaction products upon which, in part, Stadnikoff bases his argument have since been shown by Boyd and Hatt (*loc. cit.*²) to have been erroneously characterized.

The direct experimental evidence available at this writing appears insufficient to support a conclusion as to whether the first stage of the "normal" addition reaction is effected through complex rearrangement (or rearrangement and dissociation) or through complex reaction with an additional molecule of Grignard reagent. In the absence of any extremely cogent indications to the contrary, however, it seems reasonable to accept tentatively the hypothesis that the addition reactions of ketones, aldehydes, and carboxylic esters are analogous. For reasons already discussed (Chapter VI), a trimolecular process appears, in the light of present knowledge, the most probable for ketones. The rather generally applicable and, on the whole, attractive concept of a quasi six-membered ring transition state may be invoked to propose a mechanism leading to the formation of a reasonably probable (though as yet hypothetical) intermediate of the hemiketal type.

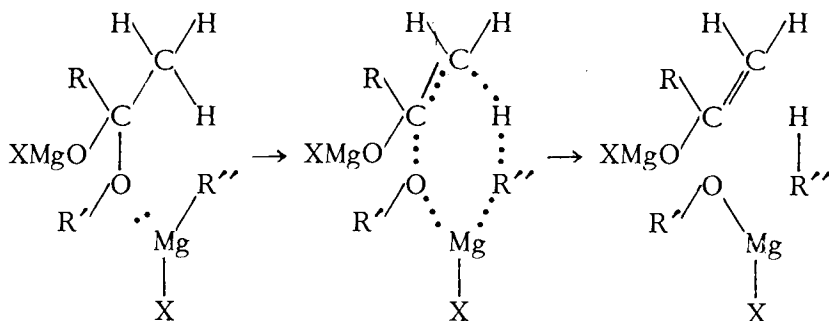
⁷Stadnikoff, *Ber.*, 47, 2133-42 (1914).



If this choice of intermediate is correct it seems probable that the succeeding reaction stage resembles that of an acetal or ketal (*q.v.*, Chapter XV), or of an ortho ester. A slightly modified version of the quasi six-membered ring transition state concept may be employed without obvious violence to the *a priori* probabilities.



The fundamental principles applicable to the elucidation of ketone enolization (see Enolate Formation by Grignard Reagents, Chapter VI) are readily extensible to a hemiketal-type intermediate of the sort postulated. Enolate formation may be conveniently represented as a concerted displacement reaction involving a quasi six-membered ring transition state.



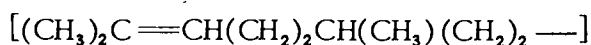
RELATIVE REACTIVITIES OF CARBOXYLIC ESTERS

Although there are a few exceptions, which will be noted in appropriate connections, the generally-prevailing impression that the course of reaction of an ester with a given Grignard reagent (say methylmagnesium bromide) is determined by the acidic constituent of the ester is not far off the mark. When no competing reaction seriously interferes, actual rates of addition are, however, affected by both the acidic and alcoholic

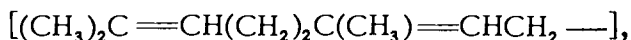
constituents of the ester. According to a kinetic study by Treibs,⁸ the influences of both acidic and alcoholic constituents upon addition rates are primarily steric rather than energetic.

The relatively simple technique of Treibs involves evaluation of a measured sample of a standard solution of methylmagnesium iodide in a 1:1 mixture of *n*-amyl ether and tetralin by measurement of the amount of methane evolved upon addition of an excess of relatively non-volatile alcohol (e.g., butyl, amyl, or benzyl). To a similar measured sample of standard Grignard solution (usually 2.0–2.5 ml.) is added 1 mole of ester, and, after a uniform time period (usually two or three minutes), residual Grignard reagent is evaluated by addition of an excess of the same non-volatile alcohol used in the control measurement. This technique, of course, makes no distinction between the first and second stages of addition, but, in so far as it is generally true that the second stage is very rapid as compared with the first, it is actually the rate of the first stage of addition that is measured.

In the cases of citronellyl



geranyl

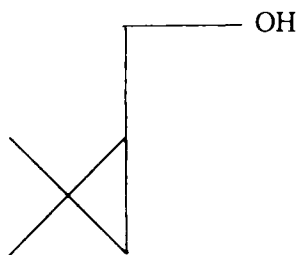


or phenethyl [$\text{C}_6\text{H}_5(\text{CH}_2)_2-$] esters of the fatty acids, the formic esters react considerably more rapidly than the corresponding acetic esters. As the acid chain is lengthened there is a further gradual drop in reactivity until the butyl esters are reached, after which further differences become negligible. That these effects are predominantly steric rather than energetic is indicated by the fact that differences in reactivity between the esters of saturated and corresponding unsaturated acids are very slight even when the unsaturation is adjacent to the functional group. Branching of the acid chain, at least in the vicinity of the functional group, retards addition. Thus, butyl butyrate, butyl isobutyrate, and butyl isovalerate are mentioned in the order of decreasing reactivity.

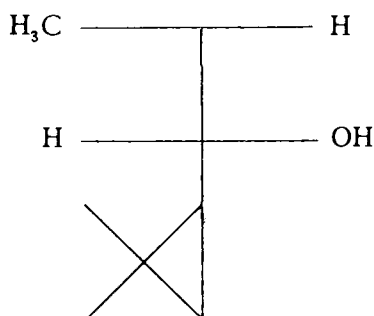
Comparison of the reactivities of corresponding esters of straight-chain, branched-chain, and variously phenylated alcohols suggests that for the alcoholic constituent the steric factor is probably relatively less influential, and the energetic factor somewhat more influential, in determining addition rates than in the case of the acid constituents.

Among the corresponding esters of terpenoid alcohols the general trend is toward greater reactivity of the esters of the less "hindered" alcohols, as the following examples show. (Reactivities are indicated in terms of molecular equivalents of methylmagnesium iodide per molecular equivalent of ester consumed in unit time.)

⁸Treibs, *Ann.*, 556, 10–22 (1944).

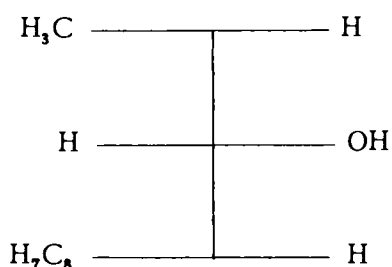
Borneol (*trans* or *endo*)

1.07



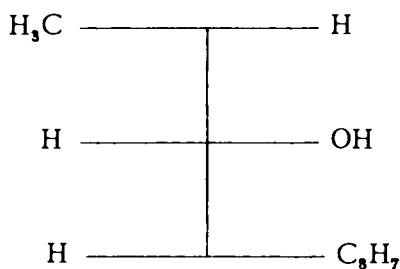
Isopinocampheol

(-)-0.94



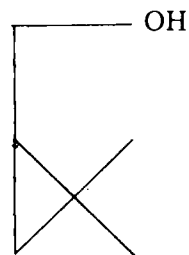
Isomenthol

(+) -1.14, (-) -1.14

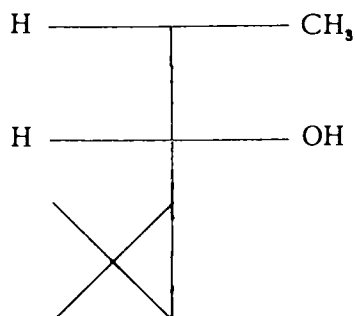


Neomenthol

(+) -0.75, (-) -0.77

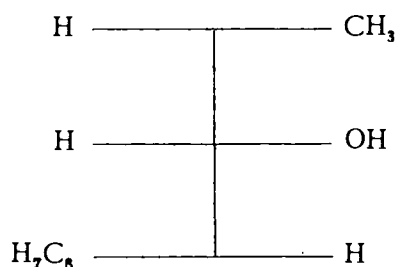
Isoborneol (*cis* or *exo*)

0.85



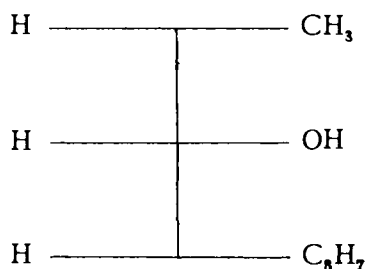
Pinocampheol

(+) -0.78



Menthol

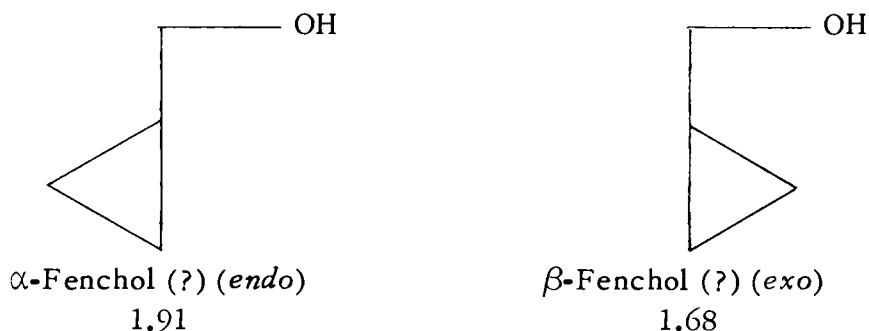
(+) -0.94, (-) -0.96



Neoisomenthol

(+) -1.23

Among the comparable isomeric esters studied, only that of neoiso-menthol appears to display a degree of reactivity inconsistent with the configuration assigned to the alcohol. That discrepancy might, conceivably, arise from experimental error. On the basis of the relative reactivities of the respective formic esters, Treibs (*loc. cit.*⁸) deduces that α -fenchol has the *endo* configuration, and β -fenchol the more highly hindered *exo* configuration.

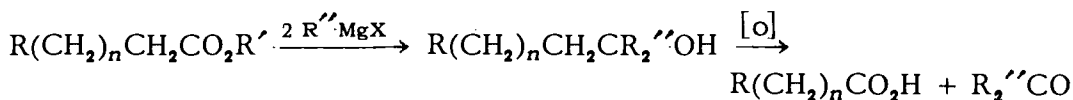


These steric influences on reactivity are compatible with, though they may by no means be regarded as critically confirmative of, the reaction mechanism tentatively proposed.

PREPARATIVE PROCEDURES

Carboxylic esters of the type $\text{RCO}_2\text{R}'$. For the preparation of tertiary alcohols by the interaction of organomagnesium halides and esters of the type $\text{RCO}_2\text{R}'$, Grignard (*loc. cit.*¹) employed essentially the same procedure as for the analogous aldehydes and ketones (see Preparative Procedures, Chapter VI). Except in special individual cases this procedure is but little modified by present-day workers. It usually consists in the gradual addition of an ethereal solution of the ester to a stirred ethereal Grignard reagent solution. When the chosen reactant pair is unusually reactive, the rate of reaction may be controlled by slower addition, or by cooling of the reaction mixture, or both. To the less active reaction mixtures heat may be applied as required. Some representative illustrative preparations are briefly outlined in Table VIII-II; references to others may be found in Table VIII-III.

The Barbier-Wieland degradation. The reaction of a Grignard reagent with a carboxylic ester constitutes the first step in a degradative process suggested by Barbier and Locquin⁹ for the successive shortening by one carbon atom of the chains of carboxylic acids or by two carbon atoms of the chains of dicarboxylic acids.



The method has been used by Wieland *et al.*¹⁰ in elucidating the structures of some of the bile acids.

A variation of the method occasionally employed in steroid research consists in dehydrating the carbinol resulting from the Grignard reaction and ozonizing the olefin thus obtained.

⁹ Barbier and Locquin, *Compt. rend.*, 156, 1443-6 (1913); *Chem. Abstr.*, 7, 3110 (1913).

¹⁰ Wieland, Schlichting, and von Langsdorff, *Z. physiol. Chem.*, 161, 74-9 (1926); Wieland, Schlichting, and Jacobi, *ibid.*, 161, 80-115 (1926); *Chem. Abstr.*, 21, 590 (1927).

TABLE VIII-II
SOME ILLUSTRATIVE PREPARATIVE REACTIONS OF GRIGNARD REAGENTS WITH CARBOXYLIC,
CARBONIC, AND ORTHO ESTERS

Reactants	Reaction Conditions	Yield* (%)	Ref.†
$\text{HCO}_2\text{C}_2\text{H}_5$ (0.25 mole) + $\text{C}_2\text{H}_5\text{MgBr}$ (0.60 mole $\text{C}_2\text{H}_5\text{Br}$)	Grad'l normal add'n; brief standing.	70	489
$\text{HCO}_2\text{C}_2\text{H}_5$ (0.75 mole) + $n\text{-C}_4\text{H}_9\text{MgBr}$ (1.50 mole $\text{C}_4\text{H}_9\text{Br}$)	Grad'l normal add'n with cooling; 10 min. stirring without cooling.	83-85	86
$\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5$ (8.30 moles) + $n\text{-C}_4\text{H}_9\text{MgBr}$ (17.25 moles $\text{C}_4\text{H}_9\text{Br}$)	Slow normal add'n; overnight standing.	79	74
$\text{BrCH}_2\text{CH}_2\text{CO}_2\text{CH}_3$ (320 g.) + CH_3MgCl (144 g. Mg)	Slow (6 hrs.) normal add'n with cooling; several hrs. at room temp.	84 (crude)	75
$\text{C}_2\text{H}_5\text{CO}_2\text{C}_2\text{H}_5$ + $\text{C}_2\text{H}_5\text{MgBr}$ (4 equiv.)	Slow normal add'n; overnight standing.	83	101,59
$n\text{-C}_3\text{H}_7\text{CO}_2\text{C}_2\text{H}_5$ + CH_3MgX (2 equiv.)	Normal add'n; 4-6 hrs. reflux.	80-85	259
Ethyl furoate (7.0 g.) + $\text{C}_6\text{H}_5\text{MgBr}$ (15.7 g. $\text{C}_6\text{H}_5\text{Br}$)	Normal add'n with reflux; 3-4 hrs. reflux.	70	147
$i\text{-C}_4\text{H}_9\text{CO}_2\text{C}_2\text{H}_5$ + $\text{C}_2\text{H}_5\text{MgX}$ (2 equiv.)	Normal add'n; 4-5 hrs. reflux.	80-85	259
Ethyl picolinate (1.00 mole) + CH_3MgI (3.25 moles)	Dropwise normal add'n with cooling; reflux to complete sol'n.	86-90	392
$t\text{-C}_4\text{H}_9\text{CH}_2\text{CO}_2\text{CH}_3$ (0.9 mole) + $n\text{-C}_4\text{H}_9\text{MgBr}$ (3.6 moles)	Slow (ca. 3.5 hrs.) normal add'n at room temp.	71	454
$(\text{C}_2\text{H}_5\text{O})_2\text{CHCO}_2\text{C}_2\text{H}_5$ (0.10 mole) + $\text{C}_6\text{H}_5\text{MgBr}$ (0.35 mole $\text{C}_6\text{H}_5\text{Br}$)	Dropwise normal add'n; 1 hr. reflux.	70	369

* The yields recorded are those of the so-called "normal" products, namely: for formates, secondary alcohols; for other carboxylates, tertiary alcohols; for carbonates, tertiary alcohols; for orthoformates, acetals or the corresponding aldehydes; and for orthocarbonates, the ortho esters.

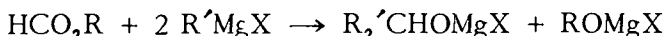
† In the interest of space economy a separate listing of references for this table is omitted; the reference numbers are those of Table VIII-III.

TABLE VIII-II (Continued)

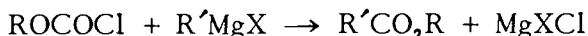
Reactants	Reaction Conditions	Yield (%)	Ref.
2-BrC ₆ H ₄ CO ₂ CH ₃ (0.9 mole) + 4-ClC ₆ H ₄ MgI (1.0 mole C ₆ H ₄ ICl)	Normal add'n; 5 hrs. reflux.	74	131
C ₆ H ₅ CO ₂ C ₂ H ₅ (75 g.) + C ₆ H ₅ MgBr (181 g. C ₆ H ₅ Br)	Grad'l normal add'n with cooling; 1 hr. reflux.	89-93	17
C ₆ H ₅ CO ₂ C ₂ H ₅ + C ₆ H ₅ CH ₂ Cl (2 equiv.) + Mg	Barbier synthesis with cooling.	60	94
(CH ₂) ₅ CHCO ₂ C ₂ H ₅ (22.5 g.) + <i>t</i> -C ₄ H ₉ C≡CMgBr (24.0 g. <i>t</i> -C ₄ H ₉ C≡CH)	Slow (3-4 hrs.) add'n of half of ester; over- night stirring; slow (4 hrs.) add'n remainder of ester; 3 hrs. stirring.	70	126
3-CH ₃ C ₆ H ₄ CO ₂ CH ₃ (13.8 g.) + C ₆ H ₅ MgBr (31.0 g. C ₆ H ₅ Br)	Dropwise normal add'n with warming; 2 hrs. warming.	81	48
CO(OC ₂ H ₅) ₂ (1.32 mole) + C ₂ H ₅ MgBr (5.00 moles C ₂ H ₅ Br)	Slow (3 hrs.) normal add'n; 1 hr. reflux with stirring.	82-88	258
HC(OC ₂ H ₅) ₃ (42.1 g.) + <i>n</i> -C ₃ H ₇ MgBr (70.0 g. C ₃ H ₇ Br)	Normal add'n; 1 hr. reflux; dist'n of Et ₂ O.	76	471
HC(OC ₂ H ₅) ₃ + C ₆ H ₅ MgBr (2 equiv.)	Slow normal add'n; 15 hrs. at room temp.; 15 min. on water-bath.	95	389
HC(OC ₂ H ₅) ₃ (0.142 mole) + 4-CH ₃ C ₆ H ₄ MgBr (0.122 mole C ₇ H ₇ Br)	Rapid normal add'n; 5 hrs. reflux; dist'n Et ₂ O; overnight standing.	74	391
C(OC ₂ H ₅) ₄ + C ₆ H ₅ MgBr (1 equiv.)	Normal add'n; 15 min. on water-bath.	70	431

Among others, Dalmer *et al.*¹¹ have used the Barbier-Wieland degradation for the conversion of 3-hydroxyallocholic acid to androsterone; Reindel and Niederlander,¹² for the preparation of lower homologs from lithocholic acid; Marker *et al.*,¹³ for a part in the preparation of *epi-allo*-pregnanolone; Morsman *et al.*,¹⁴ for the preparation of lower homologs of cholic acid; Steiger and Reichstein,¹⁵ for the degradation of 3-hydroxy- Δ^5 -cholenic acid; Hoehn and Mason,¹⁶ for the degradation of desoxycholic acid; Isihara,¹⁷ for the degradation of chenodesoxycholic acid; and Ruzicka *et al.*,¹⁸ for studies of steroids of partially known structure.

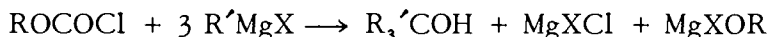
Other esters. As has already been indicated, the "normal" reaction of a formate with a Grignard reagent leads to the production of a secondary alcohol.



In chloroformic esters, which are at once esters and acid chlorides, the acid chloride function is the more reactive of the two, and among the products of reaction with one equivalent of Grignard reagent an ester usually predominates.

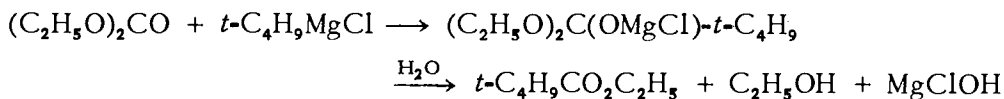


However, a tertiary alcohol, resulting from interaction of some of the Grignard reagent with the ester first formed is often one of the byproducts of the reaction, and the use of three or more equivalents of Grignard reagent with one equivalent of chloroformate usually leads to production of the carbinol.



For these reasons most of the chloroformic ester reactions have been listed in the carbonyl halide tabulation (Table IX-II), but some examples are included in Table VIII-III of this chapter.

Although the reaction of ethyl carbonate with *t*-alkylmagnesium halides tends to terminate at the first step,¹⁹



¹¹Dalmer, von Werder, Honigmann, and Heyns, *Ber.*, 68B, 1814-25 (1935).

¹²Reindel and Niederlander, *Ber.*, 68B, 1969-73 (1935).

¹³Marker, Kamm, Jones, Wittle, Oakwood, and Crooks, *J. Am. Chem. Soc.*, 59, 768 (1937); Marker, Kamm, McGinty, Jones, Wittle, Oakwood, and Crooks, *ibid.*, 59, 1367-8 (1937).

¹⁴Morsman, Steiger, and Reichstein, *Helv. Chim. Acta*, 20, 3-16 (1937).

¹⁵Steiger and Reichstein, *Helv. Chim. Acta*, 20, 1040-54 (1937).

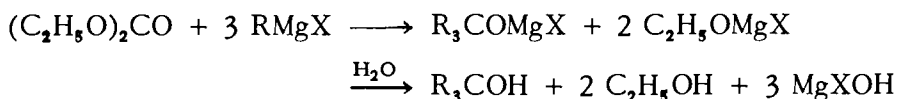
¹⁶Hoehn and Mason, *J. Am. Chem. Soc.*, 60, 1493-7 (1938).

¹⁷Isihara, *J. Biochem. (Japan)*, 27, 265-77 (1938); *Chem. Abstr.*, 33, 4265 (1939).

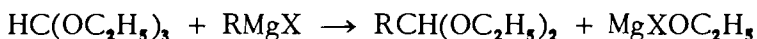
¹⁸Ruzicka, Oberlin, Wirz, and Meyer, *Helv. Chim. Acta*, 20, 1283-90 (1937).

¹⁹Whitmore and Badertscher, *J. Am. Chem. Soc.*, 55, 1559-67 (1933).

most Grignard reagents react with it to give tertiary alcohols in which all three carbinol substituents are supplied by the Grignard reagent.



The orthoformates* react readily with one equivalent of Grignard reagent to form acetals, or the corresponding aldehydes, depending on the conditions of reaction and product recovery.



Similarly, orthocarbonic ester reacts with Grignard reagents to form ortho esters.



KETONE (OR ALDEHYDE) FORMATION

For most saturated esters of the type RCO_2R' it would appear that the second step of the Grignard reaction takes place even more readily than the first, for treatment of an ester with one equivalent of Grignard reagent usually leads, not to the formation of a ketone, but of a tertiary alcohol, and to the recovery of approximately half the ester used.

In this respect formic esters are exceptions to the general rule (probably because of their relatively greater reactivity with respect to the first reaction step), for, although they usually yield secondary alcohols under ordinary Grignard reaction conditions, they can be made to yield aldehydes, as was discovered by Gattermann and Maffezzoli.²⁰ As might be expected, optimum yields of aldehydes are obtained by employing an excess of ester, by reversing the usual order of reagent addition, and by operating at low temperature. (Gattermann and Maffezzoli used three moles of ester to one of Grignard reagent at -50°). Even so, yields are never high (see Table VIII-III), and this method of preparation has been almost entirely abandoned in favor of the orthoformic ester method which gives excellent yields of the acetals (see Tables VIII-II and VIII-III).

As regards "unhindered" saturated esters other than the formates it would appear from the available data that, when the Grignard intermediate originally formed is reasonably ether-soluble, the ability to form ketones is a function primarily of the Grignard reagent employed rather than of the ester. The branched-chain alkylmagnesium halides, the pyrrolmagnesium halides, and the diortho-substituted arylmagnesium halides appear to display a special tendency toward ketone formation. This suggests that the effect is primarily steric, although in the case of the Grignard

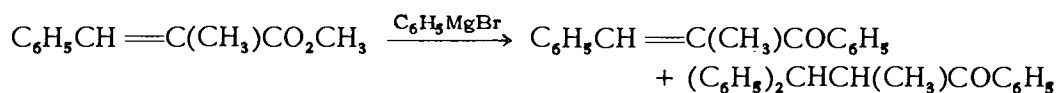
*Actually these reactions are more closely related to those of the acetals, ketals, and ethers, (*q.v.*, Chapter XV) than to those of the ordinary carboxylic esters.

²⁰Gattermann and Maffezzoli, *Ber.*, 36, 4152-3 (1903). See also: Houben, *Chem.-Ztg.*, 29, 667-8 (1905); *Chem. Zentr.*, 1905, II, 765.

reagents derived from nitrogen heterocycles by hydrogen displacement this effect may be related to one of their atypical properties. In extreme cases steric hindrance may, in itself, be sufficient to account for the inhibition of further addition. Probably, however, it is oftener the case that such inhibition results, in part at least, from the intervention of potentially competing reactions, such as enolization or reduction of the intermediate formed in the first stage of the addition.

When the intermediate formed in the first stage of the Grignard reagent addition is virtually insoluble in the reaction medium, further reaction is necessarily slow. This, as suggested by Long *et al.*,²¹ is probably the reason for the isolation of 3(α),11(α)-dihydroxynorcholanyl phenyl ketone as a byproduct of the reaction of methyl 3(α),11(α)-dihydroxycholesterol with phenylmagnesium bromide. The detection of ketones as byproducts of the reactions of steroid esters with Grignard reagents is a rather common occurrence.²²

The α,β -unsaturated esters are exceptions to the general rule in that they display a tendency toward ketone formation regardless of the nature of the Grignard reagents with which they are treated. Usually, though not invariably, ketone formation is accompanied by 1,4-addition (see Table VIII-III). Kohler²³ reported that when methyl α -methylcinnamate, in slight excess, reacts with phenylmagnesium bromide both α -benzylidenepropiophenone and α -benzhydrylpropiophenone are formed.



The reactions of Grignard reagents with the aryl esters of "hindered" acids are probably special cases of ether cleavage (*q.v.*, Chapter XV), and are discussed in the section on Ester Cleavages, p. 567.

REDUCTION

So far as may be judged from published reports, the carboxylic esters as such are not reduced by Grignard reagents. Various investigators, however, have reported the isolation of secondary alcohols corresponding to the ketones which might be expected to result from the first step of the Grignard reaction (see Table VIII-III).

The mechanism of such reductions has not been studied, but it appears that they occur only in reactions involving Grignard reagents of the type $\text{RR}'\text{CHCR}''\text{R}'''\text{MgX}$ (*i.e.*, those which also effect aldehyde and ketone reductions), and the predictable alkene byproducts ($\text{RR}'\text{C}=\text{CR}''\text{R}'''$) have been detected by Meerwein,²⁴ Leroide,²⁵ Stas,²⁶ and Ivanoff and

²¹Long, Marshall, and Gallagher, *J. Biol. Chem.*, 165, 197-209 (1946).

²²Private communication from Dr. T. F. Gallagher of the Sloan-Kettering Institute for Cancer Research.

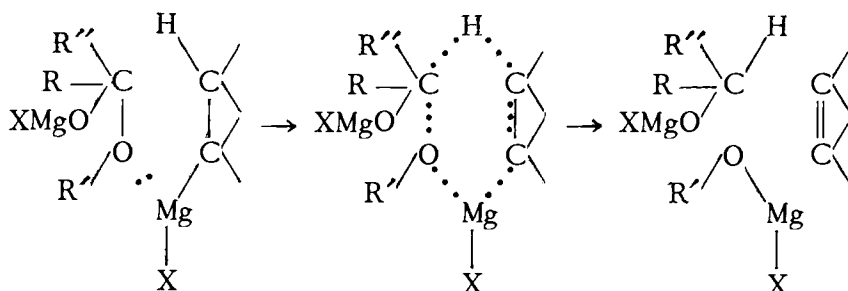
²³Kohler, *Am. Chem. J.*, 36, 529-38 (1906).

²⁴Meerwein, *Ann.*, 396, 200-63 (1913).

²⁵Leroide, *Ann. chim.*, [9], 16, 354-410 (1921).

²⁶Stas, *Bull. soc. chim. Belg.*, 34, 188-90 (1925).

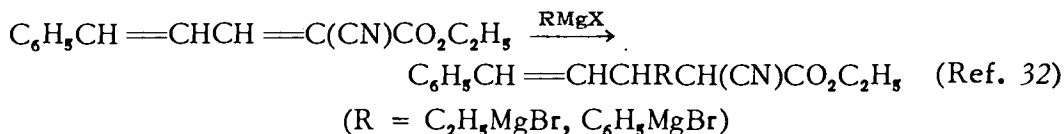
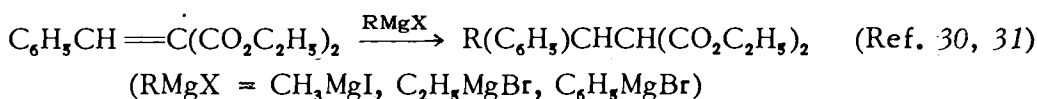
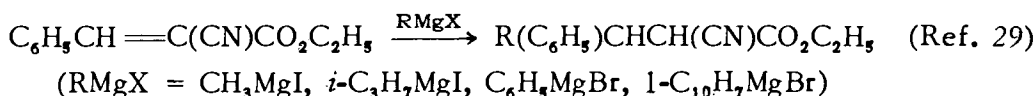
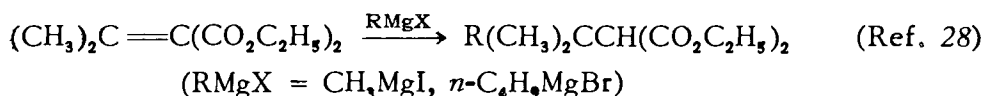
Spasoff.²⁷ If, as on the whole appears questionable, a free ketone is an intermediate in the Grignard reaction, the discussion of ketonic reduction (Chapter VI) would apply. Possibly, however, such reductions take a course illustrated by the equation:



Some reactions, therefore, may terminate at the first stage merely by reason of competition of the reduction reaction with the second stage of the Grignard reaction, rather than through any intrinsic tendency toward ketone formation.

GRIGNARD REAGENT ADDITION TO α,β -UNSATURATED CARBOXYLIC ESTERS

When treated with Grignard reagents in excess, α,β -unsaturated carboxylic esters usually undergo 1,4-addition, either with or without ketone formation. Several examples of 1,4-addition with ketone formation are recorded in Table VIII-III. Various examples of 1,4-addition without further reaction of the ester group have been reported by Kohler and his students, and by others.



²⁷Ivanoff and Spasoff, *Bull. soc. chim.*, [5], 2, 816-24 (1935).

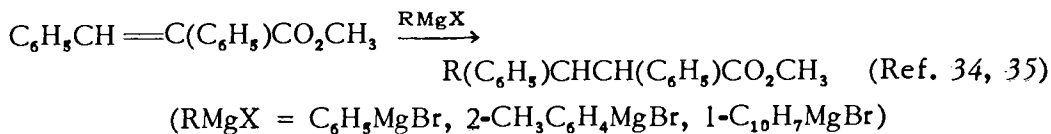
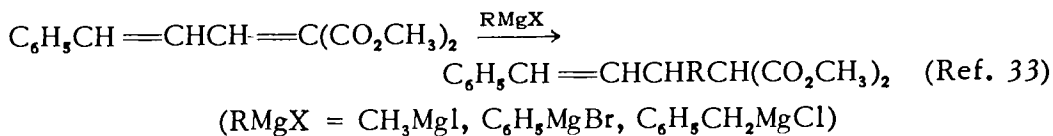
²⁸Wideqvist, *Arkiv. Kemi, Mineral. Geol.*, B23, No. 4, 6pp. (1946); *Chem. Abstr.*, 41, 1615 (1947).

²⁹Kohler and Reimer, *Am. Chem. J.*, 33, 333-56 (1905).

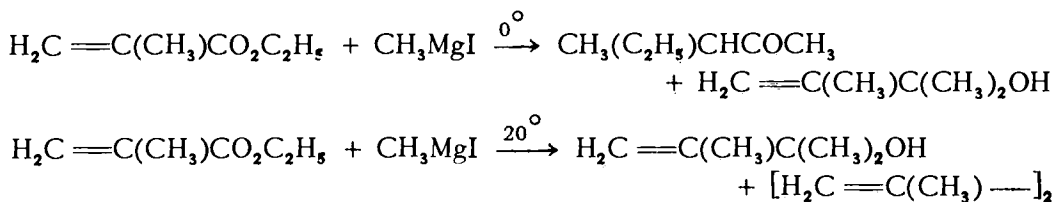
³⁰Kohler, *Am. Chem. J.*, 34, 132-47 (1906).

³¹Reynolds, *Am. Chem. J.*, 44, 305-31 (1910).

³²MacLeod, *Am. Chem. J.*, 44, 331-52 (1910).



On the basis of these observations alone one might conclude that 1,4-addition is the primary reaction of α,β -unsaturated carboxylic esters with Grignard reagents, and that ketone (or carbinol) formation are secondary reactions. However, this does not appear to be true for all esters, and for a given ester the course of the reaction may vary with the Grignard reagent and the reaction conditions employed. Blaise and Courtot³⁶ have reported, for example, that, when treated with two equivalents of methylmagnesium iodide at temperatures not exceeding 0°, methacrylic ester yields both saturated ketone and unsaturated carbinol; at 20° the products are unsaturated carbinol and bisopropenyl (neither involving 1,4-addition).



Even at 0° ethylmagnesium iodide yields only the unsaturated carbinol.

Kohler³⁷ also reports that methyl α -methylcinnamate in slight excess reacts with phenylmagnesium bromide to yield both α -benzylidenepropiophenone and α -benzhydrylpropiophenone.

CLAISEN (ACETOACETIC ESTER-TYPE) CONDENSATIONS*

Like ketones (see Enolate Formation by Grignard Reagents, Chapter VI), many esters with one or more *alpha* hydrogen atoms are capable of undergoing Grignard reagent-enolization. When such esters are also susceptible to enolate addition at the carbonyl double bond self-condensation may occur.

³³Reimer, *Am. Chem. J.*, 38, 227-37 (1907).

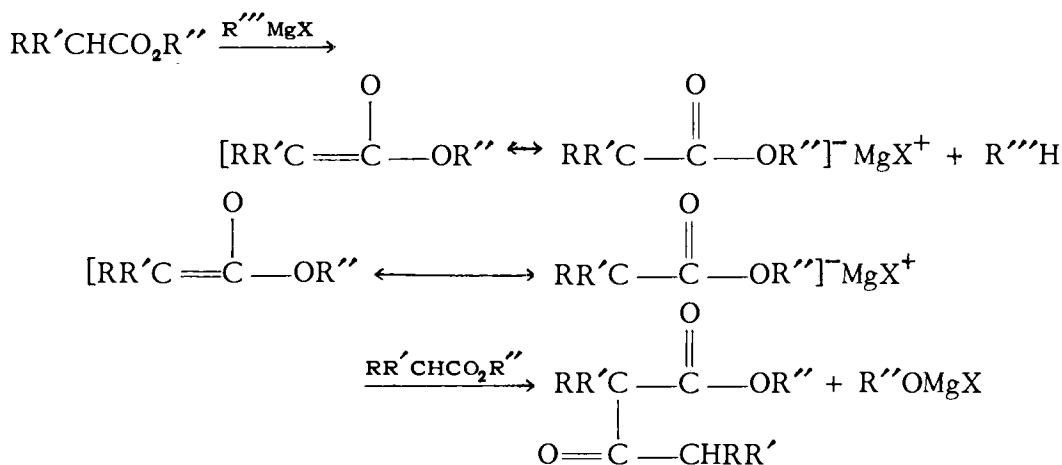
³⁴Kohler, *Am. Chem. J.*, 31, 642-6 (1904).

³⁵Kohler and Heritage, *Am. Chem. J.*, 33, 153-64 (1905).

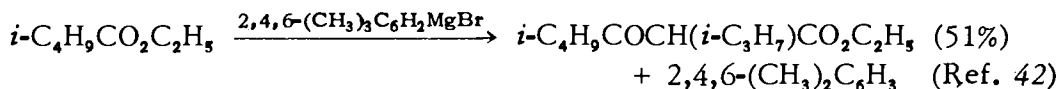
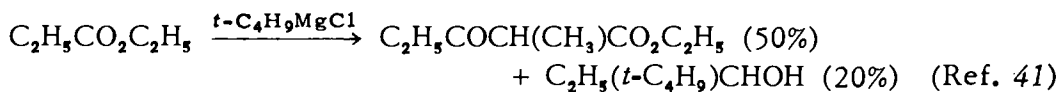
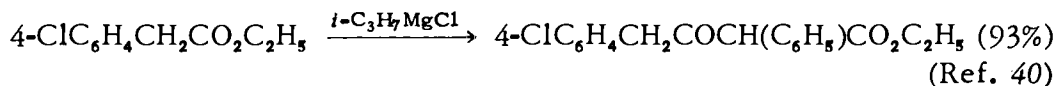
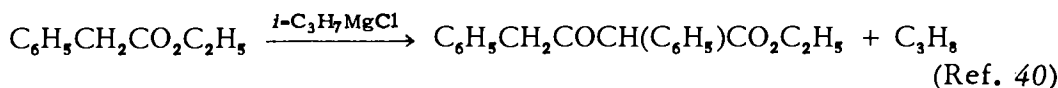
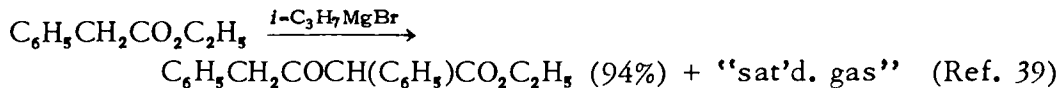
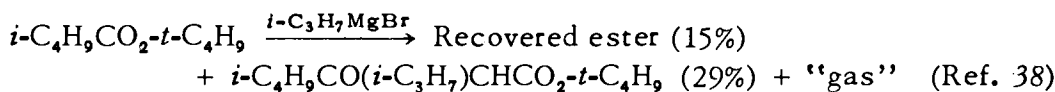
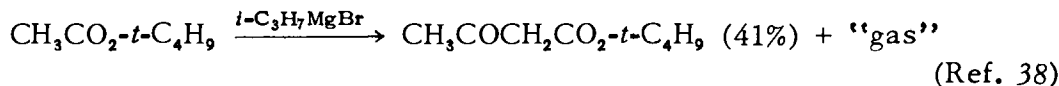
³⁶Blaise and Courtot, *Compt. rend.*, 140, 370-2 (1905); *Chem. Zentr.*, 1905, 1, 726.

³⁷Kohler, *Am. Chem. J.*, 36, 529-38 (1906).

*For a discussion of this type of reaction in general see: Hauser and Hudson, "The Acetoacetic Ester Condensations and Certain Related Reactions," Chapter 9, Vol. I of "Organic Reactions," edited by Roger Adams, John Wiley & Sons, Inc., New York, pp. 266-302, 1942.



Such condensations have been reported by Shivers *et al.*,³⁸ by Conant and Blatt,³⁹ by Ivanoff and Spassoff,⁴⁰ by Zook *et al.*,⁴¹ and by Spielman and Schmidt,⁴² and resultant analogous condensation products have undoubtedly been overlooked or ignored in many instances.



When, for steric or other reasons, an enolizable ester does not readily undergo enolate addition a cross-condensation may still be possible. Hauser *et al.*⁴³ have succeeded in benzoylating the enolate of ethyl diphenylacetate with benzoyl chloride.

³⁸Shivers, Hudson, and Hauser, *J. Am. Chem. Soc.*, 65, 2051-3 (1943).

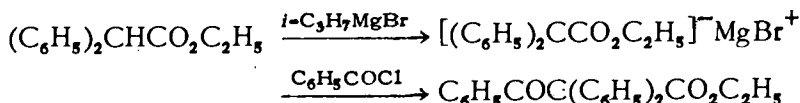
³⁹Conant and Blatt, *J. Am. Chem. Soc.*, 51, 1227-36 (1929).

⁴⁰Ivanoff and Spassoff, *Bull. soc. chim.*, [4], 49, 375-7 (1931).

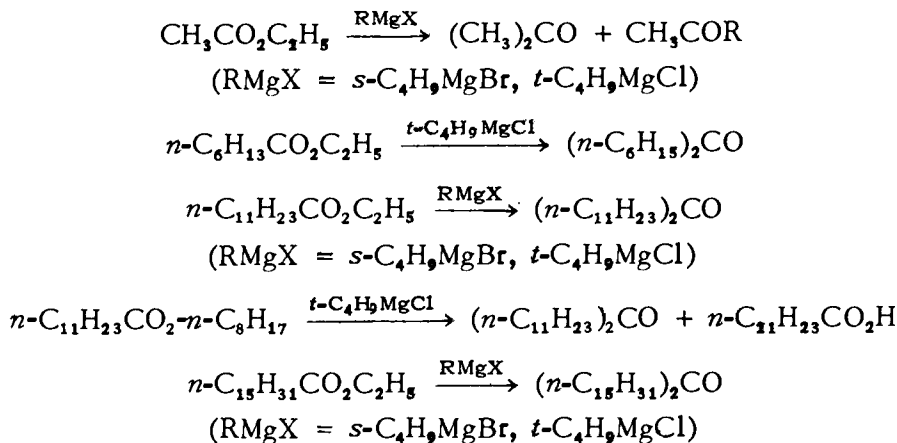
⁴¹Zook, McAleer, and Horwin, *J. Am. Chem. Soc.*, 68, 2404 (1946).

⁴²Spielman and Schmidt, *J. Am. Chem. Soc.*, 59, 2009-10 (1937).

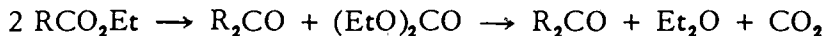
⁴³Hauser, Saperstein, and Shivers, *J. Am. Chem. Soc.*, 70, 606-8 (1948).



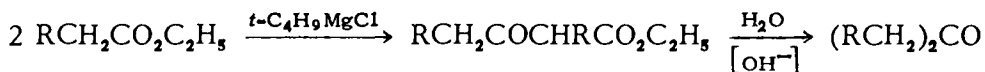
Symmetrical ketone formation (R_2CO from 2 $\text{RCO}_2\text{R}'$). Numerous examples of symmetrical ketone formation in reactions of esters with Grignard reagents in high-boiling solvents have been reported by Petrov (Pétroff) and co-workers.⁴⁴



As a reaction scheme the formulation proposed by Petrov is, of course, a palpable absurdity.



Despite the protests of Petrov,⁴⁵ there appears to be no sound reason for rejecting the suggestion of Zook *et al.* (*loc. cit.*⁴¹) that these reactions take place through the Claisen condensation, for, as they point out, the lower β -keto esters can be isolated by fractional distillation of (acid-hydrolyzed) ethereal reaction mixtures, and they have so isolated a 50 percent yield of ethyl propionylpropionate from the interaction of ethyl propionate and *t*-butylmagnesium chloride in ethereal solution.



Zook *et al.* also added an ethereal *t*-butylmagnesium chloride solution (1.08 mole) to a cooled, stirred ethereal methyl myristate (47 g., 0.32 mole) solution. Isobutane (0.17 mole) and isobutylene (0.90 mole) were evolved. After overnight standing, acid aqueous hydrolysis yielded an ether-soluble oil which was subjected to mild alkaline alcoholysis. The

⁴⁴Pétroff, Karasseff, and Tschelowa, *Bull. soc. chim.*, [5], 3, 169-76 (1936); Petrov and Sokolova, *J. Gen. Chem.* (U.S.S.R.), 8, 199-206 (1938); *Chem. Abstr.*, 32, 5376 (1938); Petrov, *Sci. Records Gorky State Univ.*, No. 7, 3-9 (1939); *Chem. Abstr.*, 35, 435 (1941); Petrov, Belyaeva, and Kukanova, *Sci. Records Gorky State Univ.*, No. 7, 14-16 (1939); *Khim. Referat. Zhur.*, 1940, No. 10-11, 20; *Chem. Abstr.*, 37, 1379 (1943).

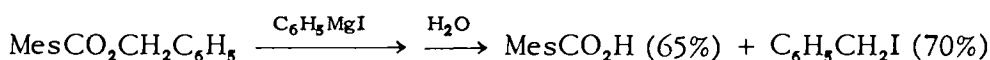
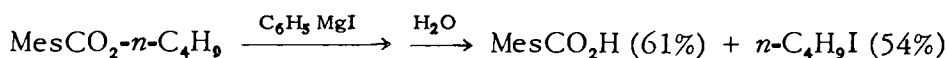
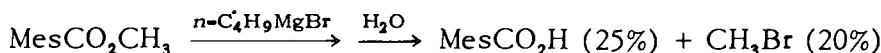
⁴⁵Petrov, *Isvest. Akad. Nauk S.S.S.R., Otdel Khim. Nauk*, 1950, 209-15; *Chem. Abstr.*, 44, 9343 (1950).

products were the relatively ether-insoluble symmetrical ketone $[(n\text{-C}_{13}\text{H}_{27})_2\text{CO}; 27.5 \text{ g.}, 44\%]$, *t*-butyltridecanylcarbinol (37 g., 40%), and myristic acid (6 g., 8%) from unchanged ester.

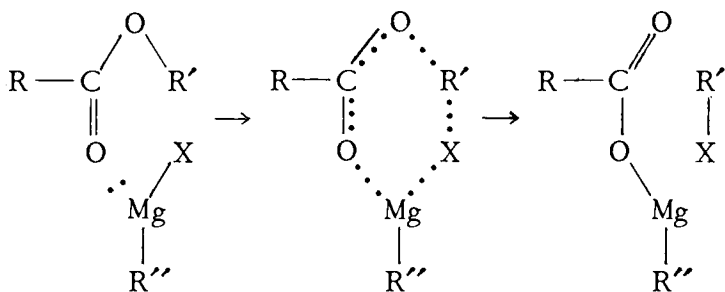
Under the experimental conditions imposed by Petrov *et al.* (*loc. cit.*⁴⁴) the decarboxylation would probably take place prior to aqueous hydrolysis.

ESTER CLEAVAGES

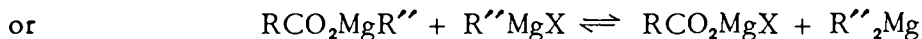
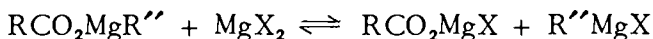
"Hindered" alkyl esters. Fuson *et al.*⁴⁶ report that methyl, *n*-butyl, and benzyl mesitoates react with Grignard reagents to yield mesitoic acid and the halides corresponding to the respective ester alcohols.



This type of reaction would appear to be most readily explicable as a special case of complex rearrangement and decomposition with carbon-oxygen bond cleavage, somewhat related to the epoxide ring openings and ether cleavages, but not closely analogous to either. Because of steric inhibition the "hindered" ester complexes presumably cannot readily react with a second molecule of Grignard reagent to effect the first step of the "normal" addition reaction, and potentially competing, but probably energetically less favored reactions, have an opportunity to come into play.



Unfortunately no one has as yet (to the knowledge of the present authors) taken the trouble to determine certainly the fate of the group R'' (corresponding to the Grignard reagent, $\text{R}''\text{MgX}$). Presumably hydrolysis of the acid salt would yield the corresponding hydrocarbon ($\text{R}''\text{H}$), although the possibility of ionic exchange in the sense



would vitiate any conclusions as to the immediate source of the hydro-

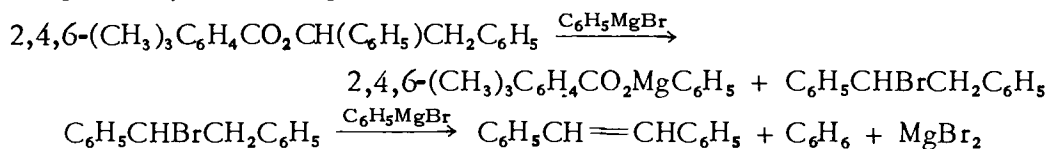
⁴⁶Fuson, Bottorff, and Speck, *J. Am. Chem. Soc.*, 64, 1450-3 (1942).

carbon unless it were possible to isolate the salt itself in a reasonably pure condition.*

Obviously the ultimate fate of the group R' would depend primarily upon the nature of the group itself, and to a lesser extent upon the nature of the Grignard reagent involved (which would necessarily determine also the identity of the halogen, X), as well as upon the experimental conditions imposed. Under ordinary reaction conditions the primary aliphatic radicals would be largely recoverable as the corresponding halides ($R'X$). Although benzyl iodide evidently does not react appreciably with the relatively unreactive phenylmagnesium iodide under the conditions employed by Fuson *et al.*, treatment of the benzyl ester with the relatively reactive benzylmagnesium chloride might lead to at least partial reaction of the halide with the Grignard reagent to form bibenzyl.⁴⁷

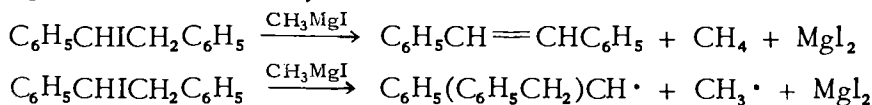
The triarylmethyl halides react readily with most Grignard reagents to give good yields of hydrocarbons (see Chapter XVI, Table XVI-I). Thus the cleavages of triphenylmethyl acetate by methylmagnesium bromide, reported by Fieser and Heymann,⁴⁸ and of triphenylmethyl benzoate by methylmagnesium iodide, reported by Hauser *et al.*,⁴⁹ to yield α,α,α -triphenylethane are readily explicable.

α,β -Diphenylethyl mesitoate might be expected to undergo Grignard reagent cleavage to yield highly reactive halides which would undergo dehydrohalogenation or coupling or both, depending on the nature of the Grignard reagent employed (see Chapter XVI). According to Hauser *et al.*, (*loc. cit.*⁴⁹) the products obtained upon treatment of the ester with phenylmagnesium bromide and with methyl- and ethylmagnesium iodides are precisely the ones predictable on this basis.



There is no need to comment on the absence of α,β -diphenylethane (a disproportionation product of the α,β -diphenylethyl radical), as do Hauser *et al.*, (*loc. cit.*⁴⁹), for this is not a free-radical reaction.

With Grignard reagents capable of undergoing both homolytic (free-radical) and heterolytic (ionic) dissociation, as is methylmagnesium iodide, both coupling and dehydrohalogenation reactions might be expected to take place simultaneously.



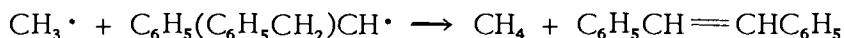
*There is, of course, the possibility that such cleavages are effected exclusively by the MgX_2 component of the Grignard reagent. Appropriate studies with R_2Mg reagents might throw some light on this point.

⁴⁷See: Späth, *Monatsh.*, 34, 1965-2014 (1913).

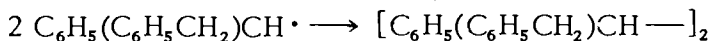
⁴⁸Fieser and Heymann, *J. Am. Chem. Soc.*, 64, 376-82 (1942).

⁴⁹Hauser, Saperstein, and Shivers, *J. Am. Chem. Soc.*, 70, 606-8 (1948).

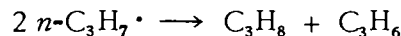
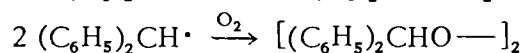
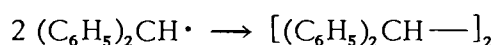
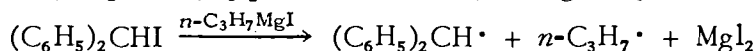
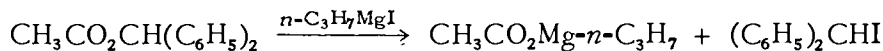
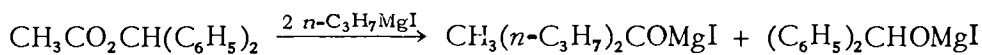
Most of the relatively reactive methyl free radicals so liberated would immediately attack the ethereal solvent, abstracting hydrogen and forming methane. A few might encounter diphenylethyl free radicals (also ready hydrogen donors), and extract hydrogen from them.



For the most part, the relatively unreactive diphenylethyl radicals would accumulate in the solution. Although the possibility of their disproportionation cannot be completely discounted, it appears probable that the predominant reaction of a free radical of this type would be dimerization.

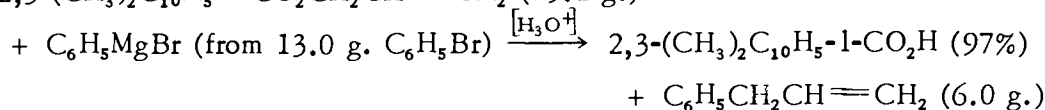
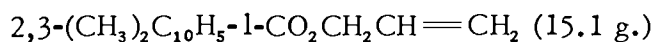
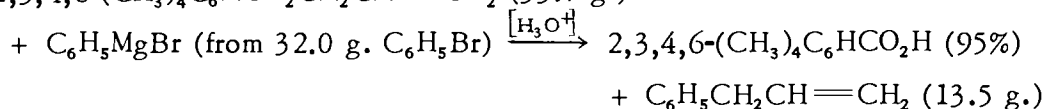
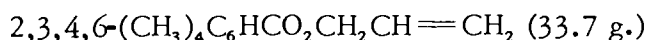


The reaction products of benzhydryl acetate with Grignard reagents (e.g., *n*-propylmagnesium iodide), as reported by Stadnikoff⁵⁰ are readily explicable on the basis indicated.



In this case the relatively unreactive *n*-propyl free radicals are unable to attack the solvent appreciably and are incapable of dimerization; consequently, they disproportionate.

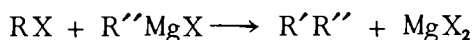
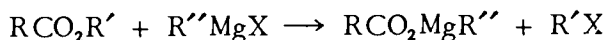
Allyl halides react readily with most Grignard reagents (except the acetylenic) to give good yields of unsaturated hydrocarbons (see Chapter XVI, Table XVI-I), and one would at first thought be inclined to attribute the cleavage of a "hindered" allyl ester by phenylmagnesium bromide to yield allylbenzene (as reported by Arnold *et al.*⁵¹) to a two-stage reaction in which allyl halide is formed by ester cleavage and then reacts with Grignard reagent.



⁵⁰Stadnikoff, *Ber.*, 47, 2133-42 (1914).

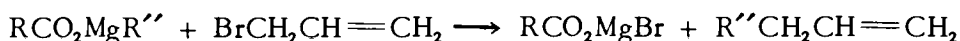
⁵¹(a) Arnold, Bank, and Liggett, *J. Am. Chem. Soc.*, 63, 3444-6 (1941); (b) Arnold and Liggett, 64, 2875-7 (1942).

Unfortunately there are at least two objections to this happy solution, the first of which might appear (like the reluctant poker player's plea of no funds) to be sufficient in itself. Analysis of the quantitative data included in the two foregoing illustrative equations reveals that in neither case could there be enough Grignard reagent present to account for a two-stage reaction in the sense:

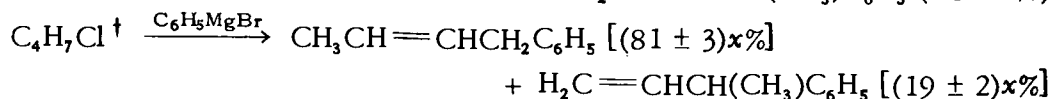
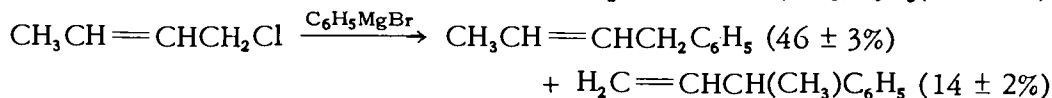
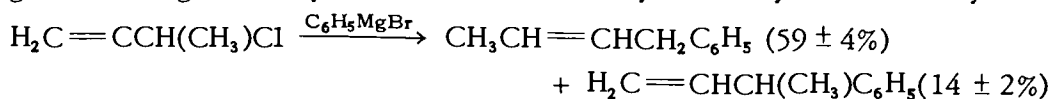


In the first instance, 0.1553 mole of ester reacts with the Grignard reagent from 0.2038 mole of bromobenzene (presumably about 0.18 mole) to form 0.1475 mole of acid and 0.1144 mole of allylbenzene. In the second, 0.0629 mole of ester reacts with the Grignard reagent from 0.0828 mole of bromobenzene (presumably about 0.08 mole) to form 0.0610 mole of acid and 0.0508 mole of allylbenzene.

Despite its apparent insuperability, however, this contra-indication might be refuted if it could be demonstrated either (a) that ionic exchange of $\text{RCO}_2\text{MgR}''$ in the sense already indicated is fairly rapid, or (b) that salts of the type $\text{RCO}_2\text{MgR}''$ (about which little or nothing is known) are to all intents and purposes Grignard reagents capable of reacting readily in the sense:



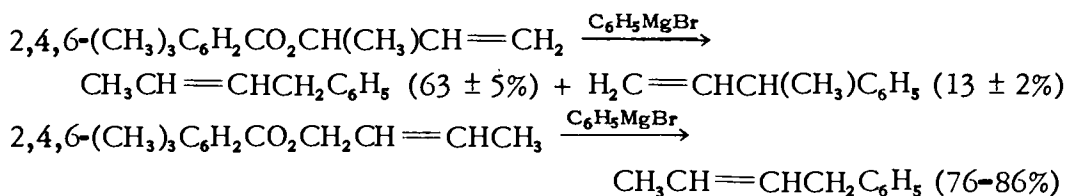
If, humanly seeking the easier course, one were inclined, tentatively, to accept the possible refutation as actual, a second objection arises out of the identities of the hydrocarbon products resulting from the phenylmagnesium bromide cleavages of the butenyl mesitoates.⁵² Although α -methallyl mesitoate yields crotylbenzene and α -methallylbenzene in approximately the same proportions that result from the treatment of either α -methallyl or crotyl chloride* with phenylmagnesium bromide, the analogous cleavage of crotyl mesitoate is said to yield crotylbenzene only.



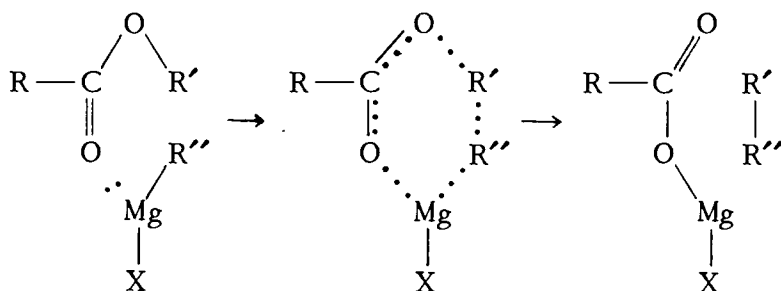
⁵²(a) Arnold and Liggett, *J. Am. Chem. Soc.*, 67, 337-8 (1945); (b) Arnold and Searles, *ibid.*, 71, 2021-3 (1949); (c) Wilson, Roberts, and Young, *ibid.*, 71, 2019-20 (1949).

*The chlorides were used in these experiments because, unlike the bromides, which isomerize rapidly at the reaction temperatures employed, they are stable. However, the stability of the *pure* chlorides at these temperatures would seem a very poor guarantee of their stability in the presence of magnesium or organomagnesium halides.

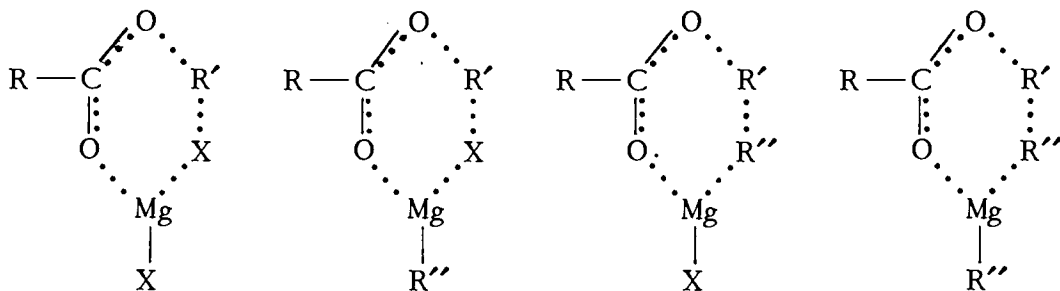
†The butenyl chloride used was a mixture of about 41% crotyl chloride and 59%



The relatively high yields of crotylbenzene obtained in the cleavage of crotyl mesitoate may or may not be, in themselves, significant, but the inability of two independent research teams to detect α -methallylbenzene among the reaction products (although classifiable as negative evidence) cannot be altogether ignored. Both Arnold and Young (*loc. cit.*⁵²) have proposed a mechanism involving a cyclic intermediate complex, which (slightly modified in form, but not materially altered in sense) may be represented as follows.



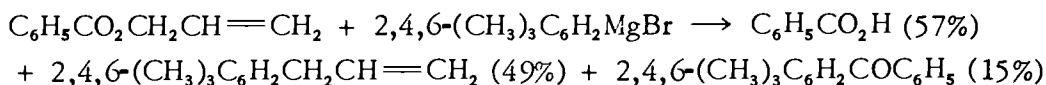
If this formulation be accepted as satisfactory and even necessary for elucidation of the Grignard cleavage of crotyl mesitoate, the question then arises why it should be inadequate to account for the mesityl ester cleavages observed by Fuson *et al.* (*loc. cit.*⁴⁶), or even (completely) for the more closely analogous α -methallyl mesitoate cleavage. At this point there arises the disquieting suspicion that this may be one of the relatively rare, but by no means unknown, situations in which the convenient, and usually harmless, fiction involved in the oversimplified $\text{R}''\text{MgX}$ formulation of the Grignard reagent (see Chapter IV) constitutes a trap for the unwary. It may well be that our speculations should take into account for any individual cleavage reaction the probable relative abundances, stabilities, and reactivities of at least four theoretically conceivable transition states.



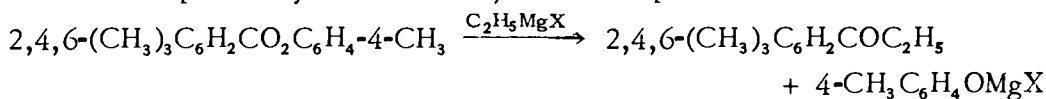
α -methallyl chloride; the products (total yield, 100x%, not stated) were isolated in the ratio indicated.

Obviously, direct experimental investigation of the proposed hypothetical $\text{RCO}_2\text{R}'\text{-R}''\text{MgX}$ complexes would be impossible, for no such thing as pure $\text{R}''\text{MgX}$ exists. Something instructive might, however, develop out of a careful quantitative study of the behavior of various $\text{RCO}_2\text{R}'\text{-MgX}_2$ and $\text{RCO}_2\text{R}'\text{-R}_2''\text{Mg}$ complexes and of the complexes formed by $\text{RCO}_2\text{R}'$ and variously-proportioned $\text{R}_2''\text{Mg-MgX}_2$ mixtures.

That "hindrance" may be a function primarily of the Grignard reagent rather than of the ester itself is indicated by the reaction of mesitylmagnesium bromide with allyl benzoate, reported by Arnold *et al.*⁵³ Under the relatively mild conditions imposed (eighteen hours at $25\text{--}35^\circ$), 57 percent of the ester reacting yielded cleavage products, whereas 15 percent gave the "normal" addition product (ketone).*



"Hindered" aryl esters. The "hindered" aryl esters undergo a different type of cleavage, yielding ketones and phenols. Several instances have been reported by Fuson *et al.*,⁵⁴ for example:



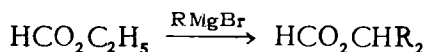
This has the formal appearance of the first stage of a "normal" ester addition, but steric considerations indicate that it must have a different mechanism. Such reactions are probably best interpreted as special cases of ether cleavage (*q.v.*, Chapter XV).

Granted that "normal" addition is sterically inhibited for both the alkyl and the aryl "hindered" esters, it would seem that the different reaction courses followed by the two types of compounds must be determined primarily by energetic factors arising out of the differences in carbon-oxygen bond polarities.

Readily enolizable ketones obtained in this manner would undoubtedly be prevented from addition by enolization.

MISCELLANEOUS BYPRODUCTS OF ESTER REACTIONS

Esterification of the expected alcohol upon reaction of a carboxylic ester with an organomagnesium halide was early observed by Grignard in the reactions of ethyl formate with isobutyl- and isoamylmagnesium bromides.



In most cases this is probably, as Stadnikov⁵⁵ believed, the result of

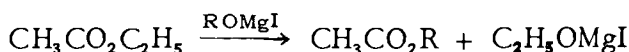
⁵³Arnold, Liggett, and Searles, *J. Am. Chem. Soc.*, 70, 3938 (1948).

*The ketone may also be a "cleavage" product (see following section).

⁵⁴Fuson, Bottorf, and Speck, *J. Am. Chem. Soc.*, 64, 1450-3 (1942).

⁵⁵Stadnikov, *J. Russ. Phys.-Chem. Soc.*, 46, 887-9 (1914); 47, 1113-21 (1915); *Chem. Abstr.*, 9, 1755,3051 (1915).

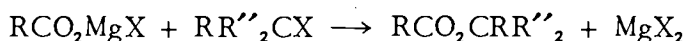
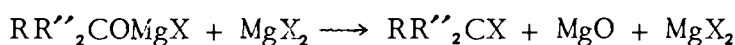
exchange between the halomagnesium alkoxide resulting from the "normal" addition reaction and the original ester. Stadnikov showed that such exchange takes place readily between ethyl acetate and the iodomagnesium derivatives of benzyl alcohol and 2-methylcyclohexanol.



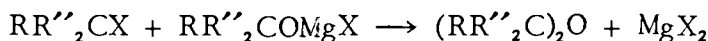
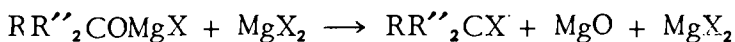
However, he observed no exchange between ethyl acetate and iodomagnesium phenoxide, or between menthyl benzoate and the iodomagnesium derivative of benzhydrol.

Concerning the probability of such exchanges he remarked: "With respect to the nature of the radicals capable of replacing each other..., it was found that with the approach of an alcohol to the phenolic state its radical becomes less capable of replacing more positive alcoholic radicals in esters. While usually the heavier radical replaces the lighter one, the reverse takes place when the difference in mass is not great and the lighter radical is the more positive. With increasing molecular weight of the acidic constituent of the ester the ability of the latter to exchange its alcoholic radical for another seems to diminish. Thus the replacement of ethyl by menthyl is slower with ethyl benzoate than with ethyl acetate or ethyl propionate."

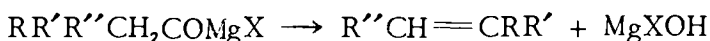
In high-temperature or "forced" reactions it is conceivable that ester formation might result from reaction of the halomagnesium salt of the acid with the halide corresponding to the expected alcohol.



As is also the case in ketone reactions, one of the products (especially in high-temperature reactions) is sometimes the ether of the expected alcohol. This undoubtedly represents a well-known special case of the Williamson ether synthesis.



In view of the facility with which many tertiary alcohols are dehydrated it is not surprising that the reaction product isolated is sometimes an olefin or mixture of olefins corresponding to the expected tertiary alcohol. In so far as dehydration occurs during the recovery of the product it may be minimized by taking the obvious precautions of avoiding excessive acidity during hydrolysis (as by the use of ammonium chloride solution), by freeing the product of all traces of acid before distillation, and by distilling at very low pressure. It is probable, however, that in some cases "dehydration" takes place prior to hydrolysis.

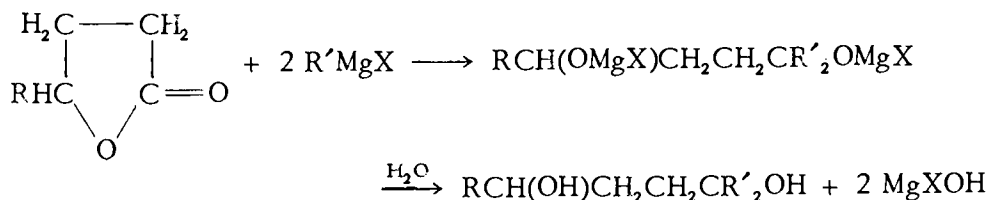


In such cases the only hope of avoiding or minimizing "dehydration" resides in conducting the reaction at as low a temperature as possible.

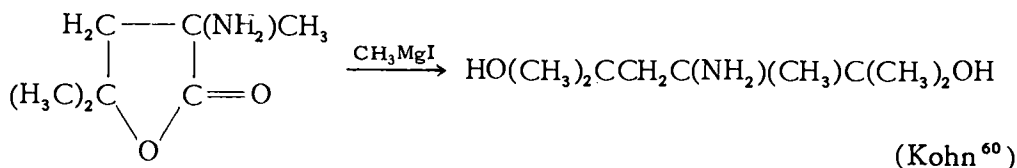
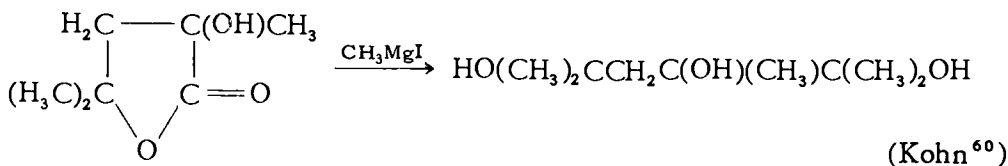
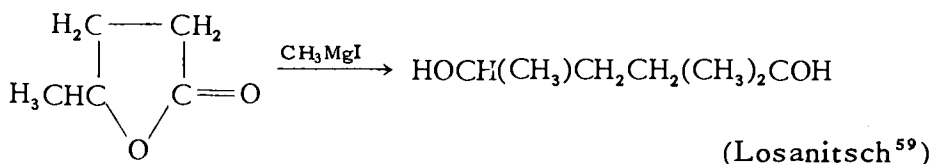
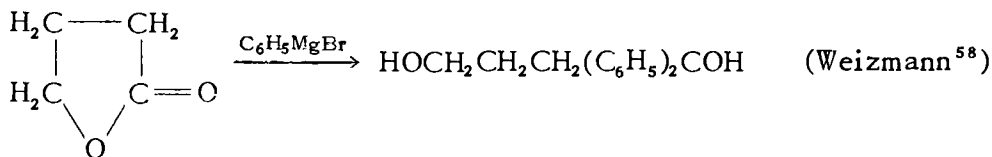
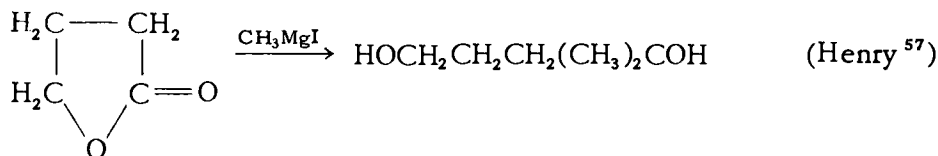
REACTIONS OF GRIGNARD REAGENTS WITH LACTONES

The reactions of Grignard reagents with lactones were first investigated by Houben⁵⁶ who studied several of the reactions of coumarin (1,2-benzopyrone).

In view of their relationship to the esters the relatively simple aliphatic γ -lactones might be expected to yield $n,n+3$ glycols.



Such reactions are reported for γ -butyrolactone, γ -valerolactone, α,γ -dihydroxy- α,γ -dimethylvaleric acid γ -lactone, α -amino- α,γ -dimethyl- γ -hydroxyvaleric acid γ -lactone, and others (see Table VIII-IV).



Cyclic etherification of the primary reaction product of lactones of this type is apparently relatively rare. Kohn (*loc. cit.*⁶⁰) reports that when an

⁵⁶Houben, *Ber.*, 37, 489-502 (1904).

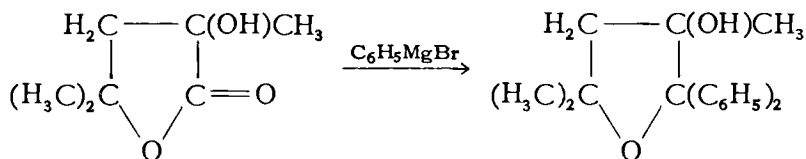
⁵⁷Henry, *Compt. rend.*, 143, 1221-5 (1906); *Chem. Zentr.*, 1907,1, 708.

⁵⁸Weizmann and Bergmann, *J. Am. Chem. Soc.*, 60, 2647-50 (1938).

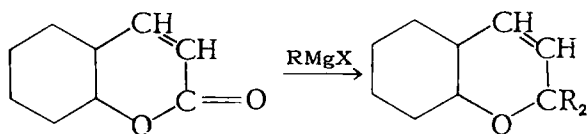
⁵⁹Losanitsch, *Compt. rend.*, 153, 390-2 (1911); *Chem. Zentr.*, 1911,11, 1118.

⁶⁰Kohn, *Monatsh.*, 34, 1729-40 (1913).

etheral solution of α,γ -dihydroxy- α,γ -dimethylvaleric acid γ -lactone is permitted to react vigorously with three equivalents of phenylmagnesium bromide the product is a tetrahydrofuran derivative,



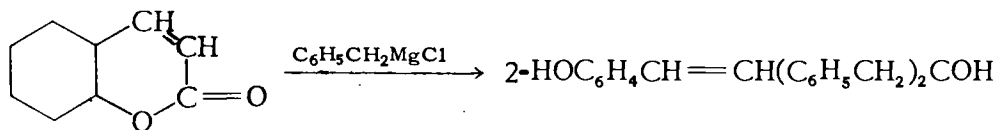
whereas, when the reaction is carried out in very high dilution, the trihydroxy open-chain product is obtained (Kohn and Ostersetzer⁶¹). With lactones of the coumarin type, however, 1,2-benzopyran (Δ^3 -chromene) formation appears to be the commoner reaction.



(Houben, *loc. cit.*,⁵⁶ Shriner⁶²)

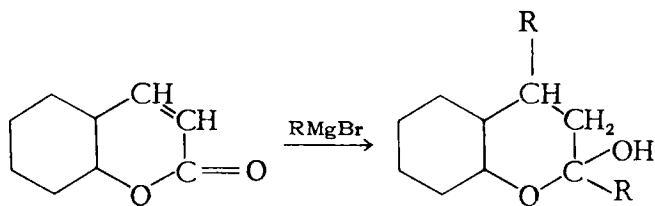
(R = CH₃, C₂H₅, *n*-C₃H₇, *n*-C₄H₉, *n*-C₅H₁₁, *n*-C₆H₁₃, *n*-C₇H₁₅)

Nevertheless, Houben (*loc. cit.*⁵⁶) claimed to have obtained with benzylmagnesium chloride, the *o*-hydroxystyrylcarbinol.



and Smith and Ruoff⁶³ report that, under carefully controlled conditions, methylmagnesium iodide, ethylmagnesium bromide, and *n*-butylmagnesium bromide may be made to yield the carbinols (or mixtures of the carbinols with the benzopyrans).

In view of the work of Löwenbein *et al.*,⁶⁴ it would appear that Houben (*loc. cit.*⁵⁶) was in error in ascribing the *o*-hydroxystyrylcarbinol structure to the product of reaction with phenylmagnesium bromide, and that the actual product is a chromanol.



(R = C₆H₅, 1-C₁₀H₇)

This reaction is the equivalent of the 1,4-addition with ketone formation

⁶¹Kohn and Ostersetzer, *Monatsh.*, 37, 37-51 (1916).

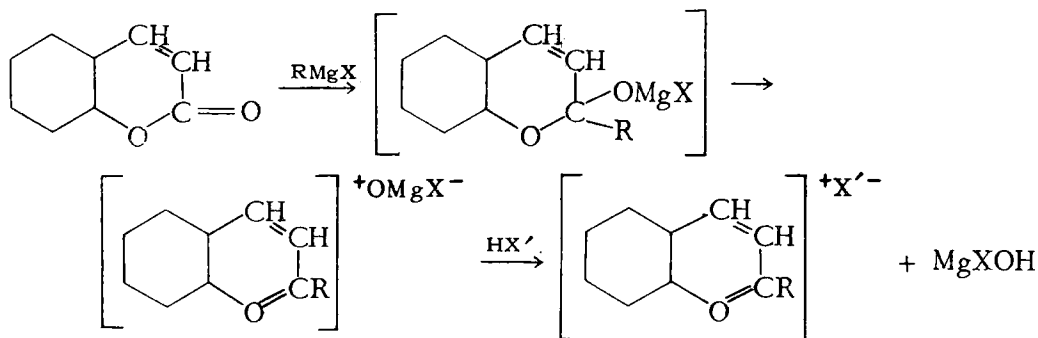
⁶²Shriner and Sharp, *J. Org. Chem.*, 4, 575-82 (1939).

⁶³Smith and Ruoff, *J. Am. Chem. Soc.*, 62, 145-8 (1940).

⁶⁴Löwenbein, Pongracz, and Spiess, *Ber.*, 57B, 1517-26 (1924).

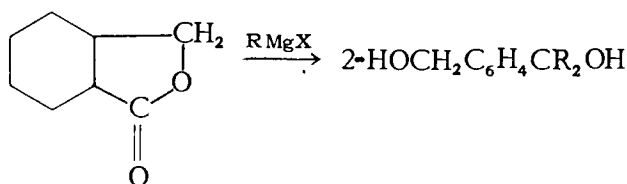
observed with the open-chain α,β -unsaturated esters. The lactone ring either is not opened or is reclosed with hemiacetal formation.

When the reaction is carried only to the first stage of 1,2-addition, without 1,4-addition, as may be accomplished by dropwise addition of the Grignard reagent to an ethereal solution of the coumarin, the product is an oxonium (benzopyrylium) salt.

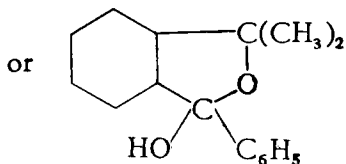
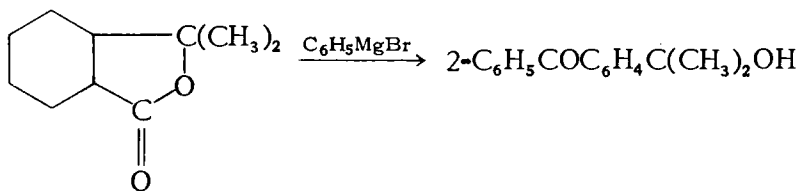


This reaction, discovered by Decker and von Fellenberg,⁶⁵ has been improved (as to yields) and extended in application by Wilstätter *et al.*^{66,67}

Phthalide is reported as reacting "normally" to yield the *o*-hydroxy-methylphenylcarbinols,^{68,69}



but 3,3-dimethylphthalide is said to yield (with phenylmagnesium bromide) either the hydroxy ketone or the corresponding phthalanol (hemiacetal).⁷⁰



⁶⁵Decker and von Fellenberg, *Ann.*, 356, 281-342 (1907).

⁶⁶Wilstätter, Zechmeister, and Kindler, *Ber.*, 57B, 1938-44 (1924).

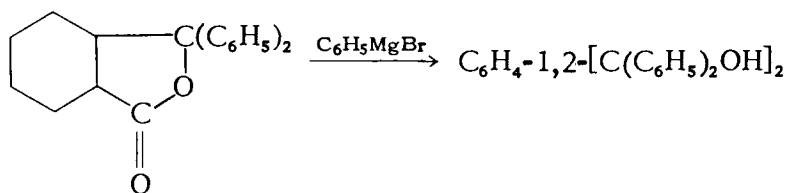
⁶⁷Wilstätter and Schmidt, *Ber.*, 57B, 1945-50 (1924).

⁶⁸Ludwig, *Ber.*, 40, 3060-5 (1907).

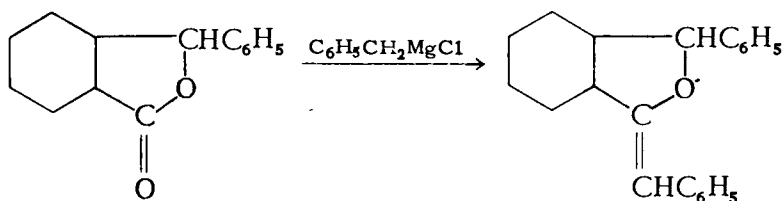
⁶⁹Seidel, *Ber.*, 61B, 2267-76 (1928).

⁷⁰Barnett, Cook, and Nixon, *J. Chem. Soc.*, 1927, 504-12.

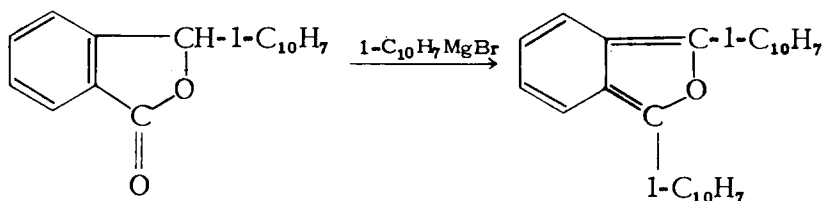
The 3-phenylphthalides are also reported as yielding phthalanols with aryl Grignard reagents,^{71,72,73} as is phthalophenone (3,3-diphenylphthalide),⁷⁴ although it is suggested by Beilstein,⁷⁵ as well as by Barnett (*loc. cit.*⁷⁰), that perhaps the latter should be formulated as the hydroxy ketone. Prolonged treatment of phthalophenone with an excess of phenylmagnesium bromide yields the glycol.⁷⁶



The interaction of a 3-arylphthalide with benzylmagnesium chloride leads to the dehydration product of the phthalanol.⁷⁷



The products of reaction of 3-*p*-tolylphthalide⁷² and 3- α -naphthylphthalide⁷⁸ with aryl Grignard reagents undergo a different type of "dehydration" to yield 3,4-benzofurans (isobenzofurans).



With aryl Grignard reagents 3-benzylidenephthalide yields 2-phenyl-3-aryllindenones.⁷⁹ At first glance it might appear that these reactions must involve a rather unusual type of rearrangement. However, if it be assumed that the Grignard reaction terminates at the first stage with the formation of a product that is at once both an enolate and a ketone, the final product is readily explicable as the result of intramolecular ketolization and "dehydration."

⁷¹Guyot and Catel, *Compt. rend.*, 140, 1348-50 (1905); *Chem. Zentr.*, 1905, 11, 137.

⁷²Guyot and Valette, *Ann. chim.*, [8], 23, 363-97 (1911).

⁷³Seidel, *Ber.*, 61B, 2267-76 (1928).

⁷⁴Guyot and Catel, *Bull. soc. chim.*, [3], 35, 551-62 (1906).

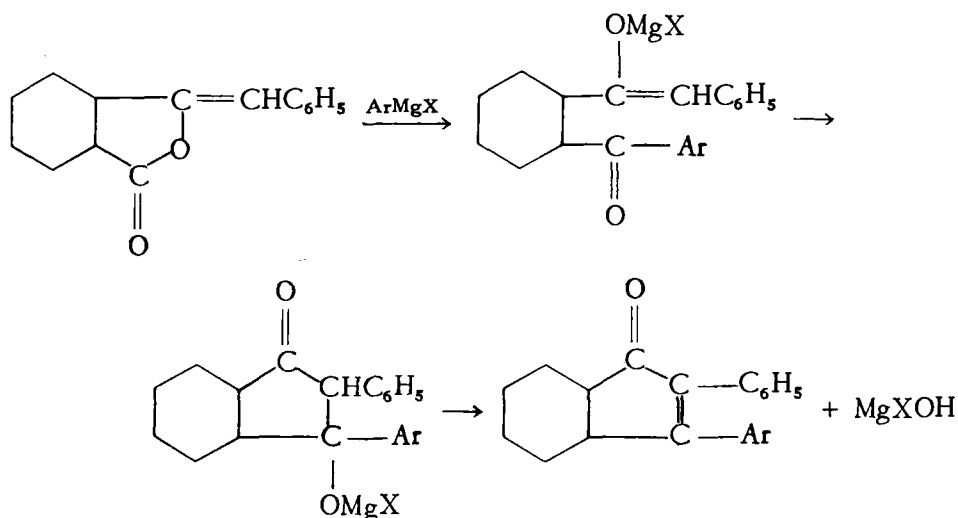
⁷⁵Beilsteins Handuch der organische Chemie, 4th ed., 8, 223 (1925).

⁷⁶Schlenk and Brauns, *Ber.*, 48, 716-28 (1915).

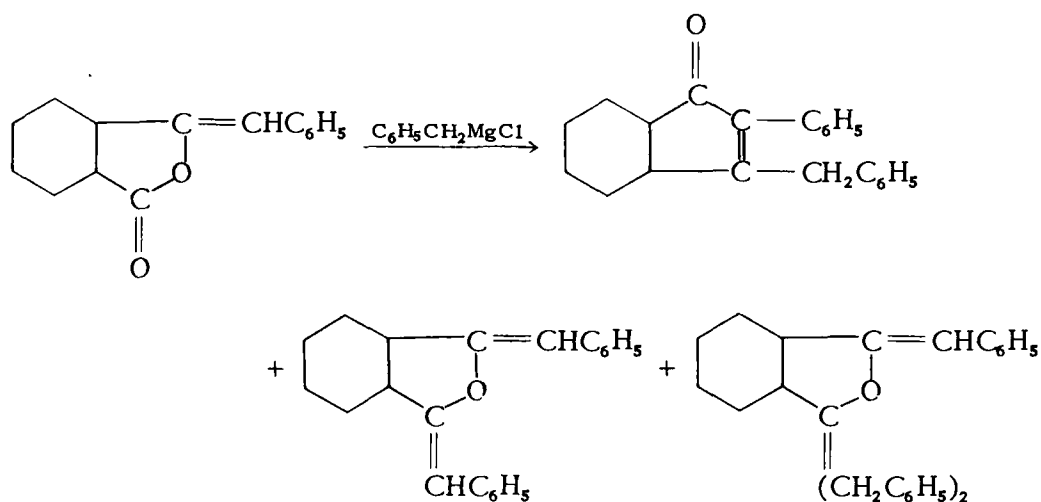
⁷⁷Weiss and Fastmann, *Monatsh.*, 47, 727-32 (1926).

⁷⁸Seer and Dischendorfer, *Monatsh.*, 34, 1493-502 (1914).

⁷⁹Weiss and Sauermann, *Ber.*, 58B, 2736-40 (1925).



With benzylmagnesium chloride this lactone undergoes both the type of reaction illustrated above and the ordinary addition-“dehydration” reactions.⁸⁰



⁸⁰Weiss, Grobstein, and Sauermann, *Ber.*, 59B, 301-6 (1926); Weiss and Alberti, *Ber.*, 59B, 220-7 (1932).

TABLE VIII-III
REACTIONS OF GRIGNARD REAGENTS WITH CARBOXYLIC, ORTHOFORMIC,
CARBONIC, AND ORTHOCARBONIC ESTERS

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CO₂Cl-R*			
ClCO ₂ C ₂ H ₅	C ₂ H ₅ MgX †	(C ₂ H ₅) ₃ COH (55%)	267
ClCO ₂ C ₂ H ₅	CH ₃ C≡CMgBr	(CH ₃ C≡C) ₃ COH; CH ₃ C≡CCO ₂ C ₂ H ₅	178
ClCO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	(<i>n</i> -C ₃ H ₇) ₃ COH	267
ClCO ₂ C ₂ H ₅ (40 g.)	C ₆ H ₅ MgBr (53 g. C ₆ H ₅ Br)	C ₆ H ₅ CO ₂ C ₂ H ₅ (36 g., 75%); (C ₆ H ₅) ₃ COH (3 g., 8.6%)	166
ClCO ₂ C ₂ H ₅ (40 g.)	C ₆ H ₅ MgBr (50 g. C ₆ H ₅ Br)	C ₆ H ₅ CO ₂ C ₂ H ₅ (8 g., 16.6%); (C ₆ H ₅) ₃ COH (12 g., 34.3%)	166
ClCO ₂ C ₂ H ₅ (50 g.)	C ₆ H ₅ CH ₂ MgCl (50 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CO ₂ C ₂ H ₅ (28 g., 43%); (C ₆ H ₅ CH ₂) ₃ COH (6 g.)	166
ClCO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl (1 equiv.)	2-CH ₃ C ₆ H ₄ CO ₂ C ₂ H ₅ ; C ₆ H ₅ CH ₂ CO ₂ H; (C ₆ H ₅ CH ₂) ₃ COH	10,478
ClCO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl (3 equiv.)	(C ₆ H ₅ CH ₂) ₃ COH (principal product)	10
ClCO ₂ C ₂ H ₅ (10 g.)	C ₁₀ H ₁₇ MgCl ‡ (0.1 mole)	Unchanged ester (55%); (C ₁₀ H ₁₇)CO ₂ C ₂ H ₅ (33%); (C ₁₀ H ₁₇)CH ₂ OH (12%)	361
ClCO ₂ C ₂ H ₅ (69 g.)	"Isomerized" C ₁₀ H ₇ MgCl § (0.5 mole)	(C ₁₀ H ₁₇)CO ₂ C ₂ H ₅ (95%)	361
ClCO ₂ C ₂ H ₅ (20 g.)	Isobornyl-MgCl ¶ (0.136 mole)	(C ₁₀ H ₁₇)CH ₂ OH (0.039 mole); bornylene	361

* For most chloroformic esters see Table IX-II. Reactions of Grignard Reagents with Carbonyl Halides.

† X = Br, I.

‡ From (+)-*α*-pinene hydrochloride; Rivière (361) concludes that this Grignard reagent is an equimolecular mixture of bornylmagnesium and isobornylmagnesium chlorides.

§ Prepared by refluxing in xylene (three hours at 130°) the Grignard reagent from (+)-*α*-pinene hydrochloride; Rivière (361) concludes that the reagent so obtained is substantially pure bornylmagnesium chloride.

¶ Prepared by partial (66%) carbonation of the Grignard reagent from (+)-*α*-pinene hydrochloride; Rivière (361) concludes that the residual reagent is substantially pure isobornylmagnesium chloride.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CO₃-R₂			
CO(OC ₂ H ₅) ₂ (1.32 mole)	C ₂ H ₅ MgBr	(C ₂ H ₅) ₃ COH (82-88%)	258,452,80
CO(OC ₂ H ₅) ₂	CH ₃ C≡CMgBr	(CH ₃ C≡C) ₃ COH; CH ₃ C≡CCO ₂ C ₂ H ₅	178
CO(OC ₂ H ₅) ₂	<i>n</i> -C ₃ H ₇ MgBr	(<i>n</i> -C ₃ H ₇) ₃ COH (75%)	258,80
CO(OC ₂ H ₅) ₂	H ₂ C≡CHC≡CMgBr	Product(s) explosive	302
CO(OC ₂ H ₅) ₂	Pyrryl-MgBr	<i>N</i> -Carbethoxypyrrrole (chiefly); ethyl 2-pyrrolicarboxylate ("a little")	517
CO(OC ₂ H ₅) ₂	<i>n</i> -C ₄ H ₉ MgBr	(<i>n</i> -C ₄ H ₉) ₃ COH (84%)	258
CO(OC ₂ H ₅) ₂	<i>n</i> -C ₄ H ₉ MgBr	(<i>n</i> -C ₄ H ₉) ₃ COH (80%)	462,80
CO(OC ₂ H ₅) ₂	<i>t</i> -C ₄ H ₉ MgCl (1 equiv.)	<i>t</i> -C ₄ H ₉ CO ₂ C ₂ H ₅ (56%)	452
CO(OC ₂ H ₅) ₂	<i>i</i> -C ₃ H ₇ C≡CMgBr	(<i>i</i> -C ₃ H ₇ C≡C) ₃ COH (45%)	411
CO(OC ₂ H ₅) ₂ (590 g.)	(CH ₂) ₄ CHMgBr (363 g. C ₅ H ₉ Br)	(CH ₂) ₄ CHCO ₂ C ₂ H ₅ (275 g., 48.5%)	453
CO(OC ₂ H ₅) ₂	<i>n</i> -C ₅ H ₁₁ MgBr	(<i>n</i> -C ₅ H ₁₁) ₃ COH (55%)	461,80
CO(OC ₂ H ₅) ₂	<i>n</i> -C ₅ H ₁₁ MgBr	(<i>n</i> -C ₅ H ₁₁) ₃ COH (75%)	258
CO(OC ₂ H ₅) ₂	<i>t</i> -C ₅ H ₁₁ MgCl (1 equiv.)	<i>t</i> -C ₅ H ₁₁ CO ₂ C ₂ H ₅ (trace); recovered ester	452
CO(OC ₂ H ₅) ₂ (0.33 equiv.)	<i>t</i> -C ₄ H ₉ C≡CMgBr (40 g. C ₆ H ₁₀)	(<i>t</i> -C ₄ H ₉ C≡C) ₃ COH (18-23 g., 40-50%)	518
CO(OC ₂ H ₅) ₂	C ₆ H ₅ CH ₂ MgCl	(C ₆ H ₅ CH ₂) ₃ COH (principal product); low-boiling liquid (trace)	10
CO(OC ₂ H ₅) ₂	C ₆ H ₅ CH ₂ MgCl + <i>i</i> -C ₃ H ₇ MgBr	(C ₆ H ₅ CH ₂) ₃ COH; C ₆ H ₅ CH ₂ COCH(C ₆ H ₅)CO ₂ C ₂ H ₅	181
CO(OC ₂ H ₅) ₂	<i>n</i> -C ₇ H ₁₅ MgBr	(<i>n</i> -C ₇ H ₁₅) ₃ COH (72%)	258
CO(OC ₂ H ₅) ₂	C ₆ H ₅ C≡CMgBr	(C ₆ H ₅ C≡C) ₃ COH	177
CO(OC ₂ H ₅) ₂ (12 ml.)	CH ₃ (C ₂ H ₅) ₂ CC≡CMgBr (33 g. C ₈ H ₁₄)	[CH ₃ (C ₂ H ₅) ₂ CC≡C] ₃ COH (30 g., 84%)	519

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CO₂-R₂ (cont.)			
CO(OC ₂ H ₅) ₂ (7.5 moles)	1-C ₁₀ H ₇ MgBr (5 moles)	1-C ₁₀ H ₇ CO ₂ C ₂ H ₅ (70%)	246
CO(OC ₂ H ₅) ₂ (10.5 g.)	4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ MgBr (75 g. C ₁₀ H ₁₃ Br)	(4- <i>t</i> -C ₄ H ₉ C ₆ H ₄) ₃ COH (34 g.)	257
CO(OC ₂ H ₅) ₂ (0.5 mole)	C ₁₀ H ₁₇ MgCl* (0.5 mole)	(C ₁₀ H ₁₇)CO ₂ C ₂ H ₅ (0.17 mole); (C ₁₀ H ₁₇)CH ₂ OH (0.06 mole); bornylene (0.25 mole)	361
CO(OC ₂ H ₅) ₂ (0.35 mole)	"Isomerized" C ₁₀ H ₁₇ MgCl† (0.35 mole)	(C ₁₀ H ₁₇)CO ₂ C ₂ H ₅ (68%)	361
CO(OC ₂ H ₅) ₂ (13 g.)	4- <i>t</i> -C ₅ H ₁₁ C ₆ H ₄ MgBr (90 g. C ₁₁ H ₁₅ Br)	(4- <i>t</i> -C ₅ H ₁₁ C ₆ H ₄) ₃ COH (yielding 7 g. corresponding chloride)	257
CO(OC ₂ H ₅) ₂ (3 ml.)	3-C ₆ H ₅ C ₆ H ₄ MgBr (20 g. C ₁₂ H ₉ Br)	(3-C ₆ H ₅ C ₆ H ₄) ₃ COH (12 g., crude)	256
CO₂-R₄			
C(OC ₂ H ₅) ₄	C ₂ H ₅ MgI	C ₂ H ₅ C(OC ₂ H ₅) ₃ ; CO(OC ₂ H ₅) ₂ (?); C ₂ H ₅ C(OC ₂ H ₅) ₂ CH(CH ₃)CO ₂ C ₂ H ₅	431
C(OC ₂ H ₅) ₄	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₅ H ₁₁ C(OC ₂ H ₅) ₃ (50-60%)	431
C(OC ₂ H ₅) ₄	C ₆ H ₅ MgBr	C ₆ H ₅ C(OC ₂ H ₅) ₃ (80%)	431
C(OC ₂ H ₅) ₄	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CHC(OC ₂ H ₅) ₃ (ca. 40%)	431
C(OC ₂ H ₅) ₄	C ₆ H ₅ C≡CMgI (1 equiv.)	C ₆ H ₅ C≡CC(OC ₂ H ₅) ₃	491
C(OC ₂ H ₅) ₄	C ₆ H ₅ C≡CMgI	(C ₆ H ₅ C≡C) ₂ C(OC ₂ H ₅) ₂	492
C(OC ₂ H ₅) ₄ (15 ml.)	(=CHC ₆ H ₄ -4-MgI) ₂ (6 g. C ₁₄ H ₁₀ I ₂)	[=CHC ₆ H ₄ -4-C(OC ₂ H ₅) ₃] ₂ (2.5 g., crude)	365
CHO₂-R			
HCO ₂ CH ₃	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CH ₂ CHOH (82.5%, crude)	303
HCO ₂ CH ₃	[—(CH ₂) ₅ MgBr] ₂	[—(CH ₂) ₁₀ CH(OH)—] _x † (88%)	76

* From (+)- α -pinene hydrochloride; Rivière (361) concludes that this Grignard reagent is an equimolecular mixture of bornylmagnesium and isobornylmagnesium chlorides.

† Prepared by refluxing in xylene (three hours at 130°) the Grignard reagent from (+)- α -pinene hydrochloride; Rivière (361) concludes that the reagent so obtained is substantially pure bornylmagnesium chloride.

! x averages ca. 5.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CHO₂-R (cont.)			
HCO ₂ C ₂ H ₅	(≡CMgBr) ₂	(HC≡C) ₂ CHOH	239
HCO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	(C ₂ H ₅) ₂ CHOH (73%)	135,196, 307,467, 493
HCO ₂ C ₂ H ₅ (500 parts)	C ₂ H ₅ MgI (156 parts C ₂ H ₅ I)	C ₂ H ₅ CHO	115
HCO ₂ C ₂ H ₅ (excess)	CH ₃ C≡CMgBr	(CH ₃ C≡C) ₂ CHOH	443,176,178
HCO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	(<i>n</i> -C ₃ H ₇) ₂ CHOH (88%)	433,196,307
HCO ₂ C ₂ H ₅ (18 g.)	<i>i</i> -C ₃ H ₇ MgBr (62 g. C ₃ H ₇ Br)	(<i>i</i> -C ₃ H ₇) ₂ CHOH	306
HCO ₂ C ₂ H ₅	5-Bromo-2-thienyl-MgBr	5-Bromo-2-thiophenecarboxaldehyde (10%)	124
HCO ₂ C ₂ H ₅	2-Thienyl-MgBr	2-Thiophenecarboxaldehyde (15%)	124
HCO ₂ C ₂ H ₅	Pyrryl-MgBr	2-Pyrrolicarboxaldehyde	427
HCO ₂ C ₂ H ₅	Pyrryl-MgI	2-Pyrrolicarboxaldehyde (3.0-3.5 g., 33-35%); recovered pyrrole	348
HCO ₂ C ₂ H ₅ (13 g., 0.17 mole)	Butenyl-MgBr (0.35 mole)	[H ₂ C≡CHCH(CH ₃) ₂ CHOH (two forms, totaling 18.6 g., 78%)	472
HCO ₂ C ₂ H ₅ (0.75 mole)	<i>n</i> -C ₄ H ₉ MgBr (1.5 mole C ₄ H ₉ Br)	(<i>n</i> -C ₄ H ₉) ₂ CHOH (83-85%)	82,95,251, 433
HCO ₂ C ₂ H ₅	<i>i</i> -C ₄ H ₉ MgBr	(<i>i</i> -C ₄ H ₉) ₂ CHOH; HCO ₂ CH(<i>i</i> -C ₄ H ₉) ₂	135,125
HCO ₂ C ₂ H ₅	<i>i</i> -C ₄ H ₉ MgBr	(<i>i</i> -C ₄ H ₉) ₂ CHOH (74%)	450,493
HCO ₂ C ₂ H ₅ (36 g., 0.5 mole)	<i>s</i> -C ₄ H ₉ MgBr (1 mole)	(<i>s</i> -C ₄ H ₉) ₂ CHOH (18.2 g., 13%); olefin-containing gas	472
HCO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ C≡CMgBr (2 equiv.)	(<i>n</i> -C ₃ H ₇ C≡C) ₂ CHOH	245,494
HCO ₂ C ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr	HCO ₂ CH(<i>i</i> -C ₅ H ₁₁) ₂	135
HCO ₂ C ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr	(<i>i</i> -C ₅ H ₁₁) ₂ CHOH	493
HCO ₂ C ₂ H ₅ (222 parts)	<i>i</i> -C ₅ H ₁₁ MgBr (151 parts C ₅ H ₁₁ Br)	<i>i</i> -C ₅ H ₁₁ CHO	115
HCO ₂ C ₂ H ₅	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ CHO (40%)	124

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CHO₂R (cont.)			
HCO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHOH	260
HCO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ CHO	125,115
HCO ₂ C ₂ H ₅ (11 g.)	C ₆ H ₅ MgBr (34 g. C ₆ H ₅ Br)	C ₂ H ₅ OCH(C ₆ H ₅) ₂ (15 g.); [(C ₆ H ₅) ₂ CH] ₂ O (6 g.)	402
HCO ₂ C ₂ H ₅	2,3-Dimethylpyrrol-MgX	4,5-Dimethyl-2-pyrrolicarboxaldehyde ("moderate yield")	3
HCO ₂ C ₂ H ₅	2,5-Dimethylpyrrol-MgX	2,5-Dimethyl-3-pyrrolicarboxaldehyde ("poor yield"); 1-formyl-2,5-dimethylpyrrole (principal product)	3
HCO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ C≡CMgBr	(<i>n</i> -C ₄ H ₉ C≡C) ₂ CHOH	245,494
HCO ₂ C ₂ H ₅	<i>t</i> -C ₄ H ₉ C≡CMgBr	(<i>t</i> -C ₄ H ₉ C≡C) ₂ CHOH	495
HCO ₂ C ₂ H ₅ (180 parts)	C ₆ H ₅ CH ₂ MgCl (126.5 parts C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CHO	115,125
HCO ₂ C ₂ H ₅ (36 g.)	C ₆ H ₅ CH ₂ MgCl (120 g. C ₇ H ₇ Cl)	(C ₆ H ₅ CH ₂) ₂ CHOH (42.6%)	130
HCO ₂ C ₂ H ₅ (22 g.)	2-CH ₃ C ₆ H ₄ MgBr (17.1 g. C ₇ H ₇ Br)	2-CH ₃ C ₆ H ₄ CHO (5.4 g., 45%); (2-CH ₃ C ₆ H ₄) ₂ CHOH	125,124
HCO ₂ C ₂ H ₅ (33.4 g.)	2-CH ₃ C ₆ H ₄ MgBr (171 g. C ₇ H ₇ Br)	(2-CH ₃ C ₆ H ₄) ₂ CHOH (70 g., 73%)	121
HCO ₂ C ₂ H ₅	3-CH ₃ C ₆ H ₄ MgBr	3-CH ₃ C ₆ H ₄ CHO	125
HCO ₂ C ₂ H ₅	4-CH ₃ OC ₆ H ₄ MgBr	4-CH ₃ OC ₆ H ₄ CHO	125
HCO ₂ C ₂ H ₅	<i>n</i> -C ₅ H ₁₁ C≡CMgBr	(<i>n</i> -C ₅ H ₁₁ C≡C) ₂ CHOH	245,494
HCO ₂ C ₂ H ₅	<i>n</i> -C ₇ H ₁₅ MgBr	(<i>n</i> -C ₇ H ₁₅) ₂ CHOH (61%)	433
HCO ₂ C ₂ H ₅	CH ₃ (<i>i</i> -C ₄ H ₉)CHCH ₂ MgBr	"Secondary products only"	433
HCO ₂ C ₂ H ₅	(<i>i</i> -C ₃ H ₇) ₂ CHMgBr	(<i>i</i> -C ₃ H ₇) ₂ CH ₂ ; <i>i</i> -C ₃ H ₇ CH=C(CH ₃) ₂ ; (<i>i</i> -C ₃ H ₇) ₂ CHCH ₂ OH	433
HCO ₂ C ₂ H ₅	C ₆ H ₅ C≡CMgBr (1 equiv.)	C ₆ H ₅ C≡CCHO	173

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CHO₂R (cont.)			
HCO ₂ C ₂ H ₅	C ₆ H ₅ C≡CMgBr (2 equiv.)	(C ₆ H ₅ C≡C) ₂ CHOH	173,245,494
HCO ₂ C ₂ H ₅	Indolyl-MgX	3-Indolecarboxaldehyde ("very little"); 1-formylindole (principal product)	3
HCO ₂ C ₂ H ₅ (41 parts)	Indolyl-MgBr (50 parts indole)	3-Indolecarboxaldehyde (41%); 1-formylindole (40%)*	99
HCO ₂ C ₂ H ₅ (10 ml.)	Indolyl-MgI (3 g. indole)	1-Formylindole (3.0-3.5 g., ca. 90%)†	348
HCO ₂ C ₂ H ₅ (10 ml.)	Indolyl-MgI (3 g. indole)	3-Indolecarboxaldehyde (1.0-1.2 g.); 1-formylindole (1.0 g.)‡	348
HCO ₂ C ₂ H ₅	2,3-(CH ₃) ₂ -4-BrC ₆ H ₂ MgBr	2,3-(CH ₃) ₂ -4-BrC ₆ H ₂ CHO (10%)	124
HCO ₂ C ₂ H ₅ (21.4 g.)	2,4-(CH ₃) ₂ C ₆ H ₃ MgBr ("twofold excess")	{[2,4-(CH ₃) ₂ C ₆ H ₃] ₂ CH}O (17 g.); [2,4-(CH ₃) ₂ C ₆ H ₃] ₂ CHOH	122
HCO ₂ C ₂ H ₅ (30 ml.)	2,5-(CH ₃) ₂ C ₆ H ₃ MgBr (18.5 g. C ₈ H ₉ Br)	2,5-(CH ₃) ₂ C ₆ H ₃ CHO (45%)	124
HCO ₂ C ₂ H ₅ (22.0 g.)	2-C ₂ H ₅ OC ₆ H ₄ MgBr (20.1 g. C ₈ H ₉ BrO)	2-C ₂ H ₅ OC ₆ H ₄ CHO (30%)	124
HCO ₂ C ₂ H ₅ (5.5 g.)	2,6-(CH ₃ O) ₂ C ₆ H ₃ MgI (25.0 g. C ₈ H ₉ IO ₂)	[2,6-(CH ₃ O) ₂ C ₆ H ₃] ₂ CHOH (8-10 g.)	21
HCO ₂ C ₂ H ₅	<i>n</i> -C ₆ H ₁₃ C≡CMgBr	(<i>n</i> -C ₆ H ₁₃ C≡C) ₂ CHOH	245
HCO ₂ C ₂ H ₅ (47 g.)	<i>n</i> -C ₈ H ₁₇ MgBr (245 g. C ₈ H ₁₇ Br)	(<i>n</i> -C ₈ H ₁₇) ₂ CHOH (41.5 g., crude); C ₁₇ H ₃₄	498
HCO ₂ C ₂ H ₅	4-CH ₃ C ₆ H ₄ C≡CMgBr	(4-CH ₃ C ₆ H ₄ C≡C) ₂ CHOH	245
HCO ₂ C ₂ H ₅	2-Methylindolyl-MgX	2-Methylindole-3-carboxaldehyde ("very little"); 1-formyl-2-methylindole (principal product)	3

* The Grignard reagent was prepared with the aid of ethylmagnesium bromide; it is said that when ethylmagnesium chloride is used the yield of 3-indolecarboxaldehyde is negligible.

† Dropwise addition of ester to ice-salt-cooled benzene-Grignard reagent solution.

‡ Dropwise addition of ester to benzene-Grignard reagent solution; twenty minutes at 70-75°.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CHO₂-R (cont.)			
HCO ₂ C ₂ H ₅	2-Methylindolyl-MgI	1-Formyl-2-methylindole*	348
HCO ₂ C ₂ H ₅	2-Methylindolyl-MgI	2-Methylindole-3-carboxaldehyde (yield "not great")†	348
HCO ₂ C ₂ H ₅	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ CH ₂ ; 2,4,6-(CH ₃) ₃ C ₆ H ₂ OH	235
HCO ₂ C ₂ H ₅	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ CH ₂ ("small am't"); [2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ CO	232
HCO ₂ C ₂ H ₅ (7.5 g.)	1-C ₁₀ H ₇ MgBr (50 g. C ₁₀ H ₇ Br)	(1-C ₁₀ H ₇) ₂ CHOH (23 g.)	375
HCO ₂ C ₂ H ₅ (15 g.)	1-C ₁₀ H ₇ MgBr (42 g. C ₁₀ H ₇ Br)	C ₂ H ₅ OCH(1-C ₁₀ H ₇) ₂	399
HCO ₂ C ₂ H ₅ (11 g.)	2-C ₁₀ H ₇ MgI (75 g. C ₁₀ H ₇ I)	(2-C ₁₀ H ₇) ₂ CHOH (9.5 g.); "β,β-dinaphthofluorene", † m. 190.5° (corr.)	374
HCO ₂ C ₂ H ₅	2,4-(CH ₃) ₂ C ₆ H ₃ C≡CMgBr	[2,4-(CH ₃) ₂ C ₆ H ₃ C≡C] ₂ CHOH	245,494
HCO ₂ C ₂ H ₅ (15 g.)	2,3,5,6-(CH ₃) ₄ C ₆ H ₂ MgBr (43 g. C ₁₀ H ₁₃ Br)	[2,3,5,6-(CH ₃) ₄ C ₆ H] ₂ CH ₂ (2 g.); [2,3,5,6-(CH ₃) ₄ C ₆ H] ₂ CO	232
HCO ₂ C ₂ H ₅	C ₁₀ H ₁₇ MgCl‡	C ₁₀ H ₁₇ CH ₂ OH; bornylene; camphane; bibornyl	60
HCO ₂ C ₂ H ₅ (0.3 mole)	C ₁₀ H ₁₇ MgCl‡ (0.3 mole)	C ₁₀ H ₁₇ CH ₂ OH (0.15 mole); bornylene (0.16 mole); recovered ester (0.16 mole)	361

* Dropwise addition of ester to ice-salt-cooled Grignard reagent solution.

† Dropwise addition of ester to Grignard reagent solution; warming at 70–75°.

‡ Schmidlin and Huber (374) do not attempt to choose between the three formulations which they regard as possible for this product, namely: 12-dibenzo[*b,b*]fluorene, 12-dibenzo[*b,g*]fluorene, and 13-dibenzo[*c,g*]fluorene. The fluorenone obtained upon oxidation of the product melted at 163–165° (corr.).

§ From pinene hydrochloride.

¶ From (+)-α-pinene hydrochloride; Rivière (361) concludes that this Grignard reagent is an equimolecular mixture of bornylmagnesium and isobornylmagnesium halides.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CHO₂R (cont.)			
HCO ₂ C ₂ H ₅ (0.5 mole)	"Isomerized" C ₁₀ H ₁₇ MgCl* (0.4 mole)	Recovered ester (0.19 mole); bornylene (0.07 mole); C ₁₀ H ₁₇ CHO (0.09 mole); (C ₁₀ H ₁₇) ₂ CHOH (0.15 mole); C ₁₀ H ₁₇ CH ₂ OH (0.05 mole).	361
HCO ₂ C ₂ H ₅ (44 g.)	2-CH ₃ O-6-C ₁₀ H ₆ MgBr (45 g. C ₁₁ H ₉ BrO)	2-CH ₃ O-6-C ₁₀ H ₆ CHO (6 g., 20%)	168
HCO ₂ C ₂ H ₅	(CH ₃) ₅ C ₆ MgBr	(CH ₃) ₅ C ₆ CHO (34%)	83
HCO ₂ C ₂ H ₅	(CH ₃) ₅ C ₆ MgBr	(CH ₃) ₅ C ₆ CHROH†; (CH ₃) ₅ C ₆ CHO	85
HCO ₂ C ₂ H ₅ (15 g.)	(CH ₃) ₅ C ₆ MgBr (46 g. C ₁₁ H ₁₅ Br)	[(CH ₃) ₅ C ₆] ₂ CH ₂ (4 g.); [(CH ₃) ₅ C ₆] ₂ CO (3 g.)	232
HCO ₂ C ₂ H ₅	<i>n</i> -C ₉ H ₁₉ C≡CMgBr	(<i>n</i> -C ₉ H ₁₉ C≡C) ₂ CHOH	245,494
HCO ₂ C ₂ H ₅ (13.2 g.)	(C ₆ H ₅) ₃ CMgCl (30 g. C ₁₉ H ₁₅ Cl)	(C ₆ H ₅) ₃ CCHO (14.5 g.)	373
HCO ₂ <i>n</i> -C ₃ H ₇	Pyrryl-MgI (1 equiv.)	2-Pyrrolicarboxaldehyde (ca. 2.6 g., 28%)	427
CHO₃-R₃			
HC(OCH ₃) ₃ (320 g.)	(≡CMgBr) ₂ (109 g. C ₂ H ₅ Br)	[≡CCH(OCH ₃) ₂] ₂ (45-66%); recovered ester	469
HC(OCH ₃) ₃	4-C ₂ H ₅ OC ₆ H ₄ MgBr	4-C ₂ H ₅ OC ₆ H ₄ CH(OCH ₃) ₂	366
HC(OC ₂ H ₅) ₃	CH ₃ MgI	CH ₃ CH(OC ₂ H ₅) ₂ (ca. 25%)	429
HC(OC ₂ H ₅) ₃	(≡CMgBr) ₂	[≡CCH(OC ₂ H ₅) ₂] ₂ (38%, crude)	470,177
HC(OC ₂ H ₅) ₃	C ₂ H ₅ MgBr (2 equiv.)	C ₂ H ₅ CH(OC ₂ H ₅) ₂ (yielding 82% aldehyde)	471
HC(OC ₂ H ₅) ₃	CH ₃ C≡CMgBr	CH ₃ C≡CCH(OC ₂ H ₅) ₂	442
HC(OC ₂ H ₅) ₃ (42.1 g.)	<i>n</i> -C ₃ H ₇ MgBr (70 g. C ₃ H ₇ Br)	<i>n</i> -C ₃ H ₇ CH(OC ₂ H ₅) ₂ (yielding 15.5 g., 75.6% aldehyde)	471

* Prepared by refluxing in xylene (three hours at 130°) the Grignard reagent from (+)- α -pinene hydrochloride; Rivière (361) concludes that the reagent so obtained is substantially pure bornylmagnesium chloride.

† R = CH₃ or C₂H₅, depending upon whether CH₃X or C₂H₅X is used as "entrainer" in the preparation of the Grignard reagent.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CHO, R₃ (cont.)			
HC(OC ₂ H ₅) ₃	<i>n</i> -C ₃ H ₇ MgI	<i>n</i> -C ₃ H ₇ CH(OC ₂ H ₅) ₂ (yielding 22% aldehyde-bisulfite comp'd)	429
HC(OC ₂ H ₅) ₃	<i>n</i> -C ₃ H ₇ MgX	<i>n</i> -C ₃ H ₇ CHO + <i>n</i> -C ₃ H ₇ CH(OC ₂ H ₅) ₂ (aggregating 75% aldehyde)	57,56
HC(OC ₂ H ₅) ₃ (30 g.)	2-Furyl-MgI (2 moles C ₄ H ₃ IO)	C ₄ H ₃ OCH(OC ₂ H ₅) ₂ (yielding 34,4% aldehyde)	127
HC(OC ₂ H ₅) ₃	2-Thienyl-MgI	2-Thiophenecarboxaldehyde	142
HC(OC ₂ H ₅) ₃ (22 g.)	3-Thienyl-MgBr (10 g. C ₄ H ₃ BrS)	3-Thiophenecarboxaldehyde ("very poor yield")	520
HC(OC ₂ H ₅) ₃ (25.0 g.)	H ₂ C=C(CH ₃)CH ₂ MgCl (18.1 g. C ₄ H ₇ Cl)	H ₂ C=C(CH ₃)CH ₂ CH(OC ₂ H ₅) ₂ (5.9 g., 24%)	223
HC(OC ₂ H ₅) ₃ (49 g., 0.3 mole)	Butenyl-MgBr (0.27 mole)	H ₂ C=CHCH(CH ₃)CH(OC ₂ H ₅) ₂ (84%); CH ₃ CH=CHCH ₂ CH(OC ₂ H ₅) ₂ (<4%); recovered ester	472
HC(OC ₂ H ₅) ₃ (48 g.)	Butenyl-MgBr (63 g. crotyl-Br)	H ₂ C=CHCH(CH ₃)CH(OC ₂ H ₅) ₂ (35 g., 73%)	521
HC(OC ₂ H ₅) ₃ (48 g.)	Butenyl-MgBr (63 g. C ₄ H ₇ Br)	H ₂ C=CHCH(CH ₃)CH(OC ₂ H ₅) ₂ (35 g., 73%)	439
HC(OC ₂ H ₅) ₃	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ CH(OC ₂ H ₅) ₂	201
HC(OC ₂ H ₅) ₃	<i>i</i> -C ₄ H ₉ MgX	<i>i</i> -C ₄ H ₉ CHO + <i>i</i> -C ₄ H ₉ CH(OC ₂ H ₅) ₂ (aggregating 66% aldehyde)	57,56
HC(OC ₂ H ₅) ₃	CH ₃ O(CH ₂) ₃ MgCl	CH ₃ O(CH ₂) ₃ CH(OC ₂ H ₅) ₂ (18%)	323
HC(OC ₂ H ₅) ₃	5-Methyl-2-thienyl-MgBr	5-Methylthiophene-2-carboxaldehyde	143
HC(OC ₂ H ₅) ₃	<i>i</i> -C ₃ H ₇ C≡CMgBr	<i>i</i> -C ₃ H ₇ C≡CCH(OC ₂ H ₅) ₂	177
HC(OC ₂ H ₅) ₃ (148 g.)	<i>n</i> -C ₅ H ₁₁ MgBr (189 g. C ₅ H ₁₁ Br)	<i>n</i> -C ₅ H ₁₁ CH(OC ₂ H ₅) ₂ (yielding 45-50 g., 45-50% aldehyde)	12,11
HC(OC ₂ H ₅) ₃	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₅ H ₁₁ CH(OC ₂ H ₅) ₂ (80%)	429

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CHO₃-R₃ (cont.)			
HC(OC ₂ H ₅) ₃	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ CHO + 4-BrC ₆ H ₄ CH(OC ₂ H ₅) ₂ (aggregating 60% aldehyde)	57,56
HC(OC ₂ H ₅) ₃	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ CH(OC ₂ H ₅) ₂ (yielding <i>ca.</i> 40% aldehyde)	429
HC(OC ₂ H ₅) ₃	4-ClC ₆ H ₄ MgBr	4-ClC ₆ H ₄ CHO + 4-ClC ₆ H ₄ CH(OC ₂ H ₅) ₂ (aggregating 64% aldehyde)	57,56
HC(OC ₂ H ₅) ₃	C ₆ H ₅ MgBr (1 equiv.)	C ₆ H ₅ CHO (as bisulfite comp'd, 21.5-89.2%, depending upon reaction conditions)	389
HC(OC ₂ H ₅) ₃	C ₆ H ₅ MgBr (2 equiv.)	C ₆ H ₅ CHO (as bisulfite comp'd, 95.0%)	389
HC(OC ₂ H ₅) ₃ (74 g.)	C ₆ H ₅ MgBr (157 g. C ₆ H ₅ Br)	C ₆ H ₅ CH(OC ₂ H ₅) ₂ (yielding 98 g., 93.3% aldehyde-bisulfite comp'd)	471,55, 57,429
HC(OC ₂ H ₅) ₃	(CH ₂) ₅ CHMgBr (1 equiv.)	(CH ₂) ₅ CHCH(OC ₂ H ₅) ₂ (yielding 61.2% aldehyde-bisulfite comp'd)*	471
HC(OC ₂ H ₅) ₃	(CH ₂) ₅ CHMgBr (2 equiv.)	(CH ₂) ₅ CHCH(OC ₂ H ₅) ₃ (yielding 56% aldehyde-bisulfite comp'd)*	471
HC(OC ₂ H ₅) ₃	(CH ₂) ₅ CHMgBr (1 equiv.)	(CH ₂) ₅ CHCH(OC ₂ H ₅) ₃ (yielding 47% aldehyde-bisulfite comp'd)†	471
HC(OC ₂ H ₅) ₃	(CH ₂) ₅ CHMgBr	(CH ₂) ₅ CHCH(OC ₂ H ₅) ₃ (yielding 75% aldehyde-bisulfite comp'd)†	471
HC(OC ₂ H ₅) ₃ (148 g.)	C ₆ H ₅ CH ₂ MgCl (126 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CH(OC ₂ H ₅) ₂ (yielding 123 g., 55% aldehyde-bisulfite comp'd)	471,56
HC(OC ₂ H ₅) ₃	2-CH ₃ C ₆ H ₄ MgBr	2-CH ₃ C ₆ H ₄ CHO (73.2%)	391
HC(OC ₂ H ₅) ₃	4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ CHO (74.4%)	391,57
HC(OC ₂ H ₅) ₃	4-CH ₃ OC ₆ H ₄ MgBr	4-CH ₃ OC ₆ H ₄ CH(OC ₂ H ₅) ₂ (yielding 15% aldehyde)	429
HC(OC ₂ H ₅) ₃	(C ₂ H ₅ O) ₂ CHC≡CMgBr	[≡CCH(OC ₂ H ₅) ₂] ₂	133,502

* Gradual addition of ester to stirred Grignard reagent solution; five hours reflux with stirring; distillation of ether.

† Addition of Grignard reagent solution to Et₂O-ester solution.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CHO₂-R₃ (cont.)			
HC(OC ₂ H ₅) ₃	3-Methylcyclohexyl-MgBr	1-Methyl-3-diethoxymethylcyclohexane (yielding 4.6 g., 25% aldehyde); "methylcyclohexene"; 3,3'-dimethylbicyclohexyl	430
HC(OC ₂ H ₅) ₃	4-CH ₃ C ₆ H ₄ CH ₂ MgX	4-CH ₃ C ₆ H ₄ CH ₂ CH(OC ₂ H ₅) ₂	42
HC(OC ₂ H ₅) ₃	4-C ₂ H ₅ OC ₆ H ₄ MgBr	4-C ₂ H ₅ OC ₆ H ₄ CH(OC ₂ H ₅) ₂	366
HC(OC ₂ H ₅) ₃ (25 g.)	4-H ₂ C=CHCH ₂ C ₆ H ₄ MgBr (0.25 mole C ₉ H ₉ Br)	4-H ₂ C=CHCH ₂ C ₆ H ₄ CH(OC ₂ H ₅) ₂ (yielding 12% aldehyde)	347
HC(OC ₂ H ₅) ₃ (25 g.)	4-CH ₃ CH=CHC ₆ H ₄ MgBr (50 g. C ₉ H ₉ Br)	4-CH ₃ CH=CHC ₆ H ₄ CH(OC ₂ H ₅) ₂ (yielding 15% aldehyde)	347
HC(OC ₂ H ₅) ₃	2-CH ₃ C ₆ H ₄ (CH ₂) ₂ MgX	2-CH ₃ C ₆ H ₄ (CH ₂) ₂ CH(OC ₂ H ₅) ₂	42
HC(OC ₂ H ₅) ₃	4-CH ₃ C ₆ H ₄ (CH ₂) ₂ MgX	4-CH ₃ C ₆ H ₄ (CH ₂) ₂ CH(OC ₂ H ₅) ₂	42
HC(OC ₂ H ₅) ₃	4-C ₂ H ₅ C ₆ H ₄ CH ₂ MgX	4-C ₂ H ₅ C ₆ H ₄ CH ₂ CH(OC ₂ H ₅) ₂	42
HC(OC ₂ H ₅) ₃	2,4-(CH ₃) ₂ C ₆ H ₃ CH ₂ MgX	2,4-(CH ₃) ₂ C ₆ H ₃ CH ₂ CH(OC ₂ H ₅) ₂	42
HC(OC ₂ H ₅) ₃	2,5-(CH ₃) ₂ C ₆ H ₃ CH ₂ MgX	2,5-(CH ₃) ₂ C ₆ H ₃ CH ₂ CH(OC ₂ H ₅) ₂	42
HC(OC ₂ H ₅) ₃	2,3,6-(CH ₃) ₃ C ₆ H ₂ MgBr	2,3,6-(CH ₃) ₃ C ₆ H ₂ CHO (61.2%)	391
HC(OC ₂ H ₅) ₃	2,4,5-(CH ₃) ₃ C ₆ H ₂ MgBr	2,4,5-(CH ₃) ₃ C ₆ H ₂ CHO (71.5%)	391
HC(OC ₂ H ₅) ₃	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CHO (57.3%)	391
HC(OC ₂ H ₅) ₃	1-C ₁₀ H ₇ MgBr	1-C ₁₀ H ₇ CHO + 1-C ₁₀ H ₇ CH(OC ₂ H ₅) ₂ (aggregating 70% aldehyde)	57,56
HC(OC ₂ H ₅) ₃	4-CH ₃ C ₆ H ₄ (CH ₂) ₃ MgX	4-CH ₃ C ₆ H ₄ (CH ₂) ₃ CH(OC ₂ H ₅) ₂	42
HC(OC ₂ H ₅) ₃	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ MgX	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ CH(OC ₂ H ₅) ₂	42
HC(OC ₂ H ₅) ₃	2,4-(CH ₃) ₂ C ₆ H ₃ (CH ₂) ₂ MgX	2,4-(CH ₃) ₂ C ₆ H ₃ (CH ₂) ₂ CH(OC ₂ H ₅) ₂	42
HC(OC ₂ H ₅) ₃	2,5-(CH ₃) ₂ C ₆ H ₃ (CH ₂) ₂ MgX	2,5-(CH ₃) ₂ C ₆ H ₃ (CH ₂) ₂ CH(OC ₂ H ₅) ₂	42
HC(OC ₂ H ₅) ₃	2,4,5-(CH ₃) ₃ C ₆ H ₂ CH ₂ MgX	2,4,5-(CH ₃) ₃ C ₆ H ₂ CH ₂ CH(OC ₂ H ₅) ₂	42
HC(OC ₂ H ₅) ₃	2,3,4,6-(CH ₃) ₄ C ₆ HMGBr	2,3,4,6-(CH ₃) ₄ C ₆ HCHO (60.2%)	391
HC(OC ₂ H ₅) ₃	2,3,5,6-(CH ₃) ₄ C ₆ HMGBr	2,3,5,6-(CH ₃) ₄ C ₆ HCHO (61.4%)	391

TABLE VIII-III (Continued)

Ester	RMgX	Product(s)	Ref.
CHO_2R_3 (cont.)			
$\text{HC}(\text{OC}_2\text{H}_5)_3$	$\text{C}_{10}\text{H}_{17}\text{MgCl}^*$	2-Decalincarboxaldehyde (mixture of stereoisomers)	295
$\text{HC}(\text{OC}_2\text{H}_5)_3$	$4\text{-(CH}_2)_4\text{CHC}_6\text{H}_4\text{MgBr}$	$4\text{-(CH}_2)_4\text{CHC}_6\text{H}_4\text{CHO}$	73
$\text{HC}(\text{OC}_2\text{H}_5)_3$	$2\text{-CH}_3\text{-5-}i\text{-C}_3\text{H}_7\text{C}_6\text{H}_3\text{CH}_2\text{MgX}$	$2\text{-CH}_3\text{-5-}i\text{-C}_3\text{H}_7\text{C}_6\text{H}_3\text{CH}_2\text{CH}(\text{OC}_2\text{H}_5)_2$	42
$\text{HC}(\text{OC}_2\text{H}_5)_3$	$4\text{-}i\text{-C}_3\text{H}_7\text{C}_6\text{H}_4(\text{CH}_2)_2\text{MgX}$	$4\text{-}i\text{-C}_3\text{H}_7\text{C}_6\text{H}_4(\text{CH}_2)_2\text{CH}(\text{OC}_2\text{H}_5)_2$	42
$\text{HC}(\text{OC}_2\text{H}_5)_3$	$2,4\text{-(CH}_3)_2\text{C}_6\text{H}_3(\text{CH}_2)_3\text{MgX}$	$2,4\text{-(CH}_3)_2\text{C}_6\text{H}_3(\text{CH}_2)_3\text{CH}(\text{OC}_2\text{H}_5)_2$	42
$\text{HC}(\text{OC}_2\text{H}_5)_3$	$2,5\text{-(CH}_3)_2\text{C}_6\text{H}_3(\text{CH}_2)_3\text{MgX}$	$2,5\text{-(CH}_3)_2\text{C}_6\text{H}_3(\text{CH}_2)_3\text{CH}(\text{OC}_2\text{H}_5)_2$	42
$\text{HC}(\text{OC}_2\text{H}_5)_3$	$(\text{CH}_3)_5\text{C}_6\text{MgBr}$	$(\text{CH}_3)_5\text{C}_6\text{CHO}$ (20%); $(\text{CH}_3)_5\text{C}_6\text{H}$; $i\text{-C}_3\text{H}_7\text{OH}^\dagger$	368
$\text{HC}(\text{OC}_2\text{H}_5)_3$ (excess)	$(\text{CH}_3)_5\text{C}_6\text{MgBr}$	$(\text{CH}_3)_5\text{C}_6\text{CHO}$ (20%); $(\text{CH}_3)_5\text{C}_6\text{H}$; $(\text{CH}_3)_6\text{C}_6^\ddagger$	85
$\text{HC}(\text{OC}_2\text{H}_5)_3$	$(\text{CH}_3)_5\text{C}_6\text{MgBr}$	$(\text{CH}_3)_5\text{C}_6\text{CHO}$ (43.1%)	391
$\text{HC}(\text{OC}_2\text{H}_5)_3$	$4\text{-(CH}_2)_5\text{CHC}_6\text{H}_4\text{MgBr}$	$4\text{-(CH}_2)_5\text{CHC}_6\text{H}_4\text{CH}(\text{OC}_2\text{H}_5)_2$ (yielding 53% aldehyde)	58
$\text{HC}(\text{OC}_2\text{H}_5)_3$	$2\text{-CH}_3\text{-5-}i\text{-C}_3\text{H}_7\text{C}_6\text{H}_3(\text{CH}_2)_2\text{MgX}$	$2\text{-CH}_3\text{-5-}i\text{-C}_3\text{H}_7\text{C}_6\text{H}_3(\text{CH}_2)_2\text{CH}(\text{OC}_2\text{H}_5)_2$	42
$\text{HC}(\text{OC}_2\text{H}_5)_3$	$4\text{-}i\text{-C}_3\text{H}_7\text{C}_6\text{H}_4(\text{CH}_2)_3\text{MgX}$	$4\text{-}i\text{-C}_3\text{H}_7\text{C}_6\text{H}_4(\text{CH}_2)_3\text{CH}(\text{OC}_2\text{H}_5)_2$	42
$\text{HC}(\text{OC}_2\text{H}_5)_3$	9-Fluorenyl-MgBr	White crystalline solid, m. 255° (40%); amorphous solid (14%)	287
$\text{HC}(\text{OC}_2\text{H}_5)_3$ (30.0 g.)	$2\text{-C}_6\text{H}_5\text{CH}_2\text{C}_6\text{H}_4\text{MgBr}$ (27.5 g. $\text{C}_{13}\text{H}_{11}\text{Br}$)	$2\text{-C}_6\text{H}_5\text{CH}_2\text{C}_6\text{H}_4\text{CH}(\text{OC}_2\text{H}_5)_2$ (15.5 g.); $(\text{C}_6\text{H}_5)_2\text{CH}_2$ (7.7 g.)	36
$\text{HC}(\text{OC}_2\text{H}_5)_3$ (37.5 g.)	9-Phenanthryl-MgBr (32.5 g. $\text{C}_{14}\text{H}_9\text{Br}$)	9-Diethoxymethylphenanthrene	448
$\text{HC}(\text{OC}_2\text{H}_5)_3$ (296.4 g., 2.0 moles)	9-Phenanthryl-MgBr (514.0 g., 2.0 moles $\text{C}_{14}\text{H}_9\text{Br}$)	9-Phenanthrenecarboxaldehyde (206–216 g., 50–52%, crude; 166–174 g., 40–42%, pure)	98,287
$\text{HC}(\text{OC}_2\text{H}_5)_3$ (7.0 g.)	$(\text{C}_6\text{H}_5)_2\text{C}=\text{CHMgBr}$ (17.5 g. $\text{C}_{14}\text{H}_{11}\text{Br}$)	$(\text{C}_6\text{H}_5)_2\text{C}=\text{CHCHO}$ (53%)	516

* From 2-chlorodecalin—either stereoisomer.

† Attributable to the action of CH_3MgBr from the CH_3Br used as "entrainer" in the preparation of the Grignard reagent.

‡ Attributable to Wurtz-Fittig side-reaction in the preparation of the Grignard reagent, in which CH_3Br is used as "entrainer".

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CHO₂-R₃ (cont.)			
HC(OC ₂ H ₅) ₃	3,8-(CH ₃) ₂ -5- <i>i</i> -C ₃ H ₇ C ₁₀ H ₄ -2-MgBr	2-(C ₂ H ₅ O) ₂ CH-3,8-(CH ₃) ₂ -5- <i>i</i> -C ₃ H ₇ C ₁₀ H ₄	141
HC(OC ₆ H ₅) ₃ (60 g.)	C ₆ H ₅ MgBr (100 g. C ₆ H ₅ Br)	C ₆ H ₅ CHO (90%)	55
HC(OC ₆ H ₅) ₃	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ CHO (20%)	55
HC(OC ₆ H ₅) ₃	4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ CHO (65%); 4-CH ₃ C ₆ H ₄ CH(OC ₂ H ₅) ₂	55
C₂O₂Cl₃-R			
Cl ₃ CCO ₂ C ₂ H ₅	CH ₃ MgBr	Cl ₃ C(CH ₃) ₂ COH	160
Cl ₃ CCO ₂ C ₂ H ₅	CH ₃ MgI	Cl ₃ C(CH ₃) ₂ COH	174
C₂O₂F₃-R			
CF ₃ CO ₂ CH ₃ (0.2-0.3 mole)	C ₂ H ₅ MgI (0.8-1.2 mole)	CF ₃ (C ₂ H ₅) ₂ COH (56.0%); CF ₃ (C ₂ H ₅)CHOH (35.0%)	515
C₂O₂N-R			
NCCO ₃ C ₂ H ₅ (0.33 mole)	C ₂ H ₅ MgBr (1.00 mole)	(C ₂ H ₅) ₃ COH (16 g.); C ₂ H ₅ COC(C ₂ H ₅) ₂ OH	68
NCCO ₂ C ₂ H ₅ (6 g.)	C ₆ H ₅ MgBr (34 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ COH (3 g.)	268
C₂O₄-R₂			
(—CO ₂ CH ₃) ₂	C ₂ H ₅ MgI	[—C(CH ₃)(C ₂ H ₅)OH] ₂	118
(—CO ₂ CH ₃) ₂	C ₆ H ₅ MgBr	[—C(C ₆ H ₅) ₂ OH] ₂	437
(—CO ₂ CH ₃) ₂ (30 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (50 g. C ₉ H ₁₁ Br)	1,3,5-(CH ₃) ₃ C ₆ H ₃ + (—CO ₂ CH ₃) ₂ (16.1 g.); 2,4,6-(CH ₃) ₃ C ₆ H ₂ COCO ₂ CH ₃ (6.0 g.)	233
(—CO ₂ CH ₃) ₂ (30 g.)	1-C ₁₀ H ₇ MgBr (52 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ COCO ₂ CH ₃ (3.5 g., crude)	233
(—CO ₂ C ₂ H ₅) ₂	CH ₃ MgI	[—C(CH ₃) ₂ OH] ₂	436
(—CO ₂ C ₂ H ₅) ₂ (73 g.)	CH ₃ MgI (180 g. CH ₃ I)	HO(CH ₃) ₂ CCO ₂ C ₂ H ₅ (39.6 g., 60%)	163,152
(—CO ₂ C ₂ H ₅) ₂	C ₂ H ₅ MgBr	[—C(C ₂ H ₅) ₂ OH] ₂ ("poor yield"); HO(C ₂ H ₅) ₂ CCO ₂ C ₂ H ₅	281

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂O₄R₂ (cont.)			
(—CO ₂ C ₂ H ₅) ₂ (73 g.)	C ₂ H ₅ Br (131 g.) + Mg (31 g.)	HO(C ₂ H ₅) ₂ CCO ₂ C ₂ H ₅ (45.5 g., 57%); recovered ester (ca. 4.0 g.)	163
(—CO ₂ C ₂ H ₅) ₂	C ₂ H ₅ MgI	HO(C ₂ H ₅) ₂ CCO ₂ C ₂ H ₅ (54.3%); [—C(C ₂ H ₅) ₂ OH] ₂ (7.1%)	395
(—CO ₂ C ₂ H ₅) ₂ (65 g.)	<i>n</i> -C ₄ H ₉ MgBr (250 g. C ₄ H ₉ Br)	HO(<i>n</i> -C ₄ H ₉) ₂ CCO ₂ C ₂ H ₅ (yielding 10 g. acid); HO(<i>n</i> -C ₄ H ₉) ₂ CCO- <i>n</i> -C ₄ H ₉ (ca. 50 g.)	331
(—CO ₂ C ₂ H ₅) ₂	<i>n</i> -C ₄ H ₉ MgBr ("1 equiv."*)	HO(<i>n</i> -C ₄ H ₉) ₂ CCO ₂ C ₂ H ₅	331
(—CO ₂ C ₂ H ₅) ₂	<i>t</i> -C ₄ H ₉ MgCl ("2 equiv."†)	<i>t</i> -C ₄ H ₉ CH(OH)CO ₂ C ₂ H ₅ ; <i>i</i> -C ₄ H ₈ ; <i>t</i> -C ₄ H ₉ CH(OC ₂ H ₅)CO ₂ C ₂ H ₅ ; [—CH(OH)- <i>t</i> -C ₄ H ₉] ₂ (?); <i>t</i> -C ₄ H ₉ COCH ₂ - <i>t</i> -C ₄ H ₉	102
(—CO ₂ C ₂ H ₅) ₂ (0.385 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.54 mole)	<i>t</i> -C ₄ H ₉ CH(OH)CO ₂ H + <i>t</i> -C ₄ H ₉ CH(OH)CO ₂ C ₂ H ₅ (aggregating 28 g. crude acid); <i>i</i> -C ₄ H ₈ (0.7 mole); (<i>i</i> -C ₄ H ₈) ₂ ; (<i>t</i> -C ₄ H ₉ —) ₂ ‡	156
(—CO ₂ C ₂ H ₅) ₂ (0.676 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.35 mole)	<i>t</i> -C ₄ H ₉ CH(OH)CO ₂ C ₂ H ₅ (27 g.); HO(<i>t</i> -C ₄ H ₉) ₂ CCO ₂ C ₂ H ₅ (?) (30 g.); high-boiling material (26 g.)§	156
(—CO ₂ C ₂ H ₅) ₂ (1 mole)	<i>t</i> -C ₄ H ₉ Cl (2 moles) + Mg	<i>t</i> -C ₄ H ₉ CH(OH)CO ₂ C ₂ H ₅ (38 g., crude); HO(<i>t</i> -C ₄ H ₉) ₂ CCO ₂ C ₂ H ₅ (40 g.); HO(<i>t</i> -C ₄ H ₉) ₂ CCO- <i>t</i> -C ₄ H ₉ (?) (39 g.)¶	156
(—CO ₂ C ₂ H ₅) ₂ (7 g.)	C ₆ H ₅ MgBr (39 g. C ₆ H ₅ Br)	C ₆ H ₅ COC(C ₆ H ₅) ₃	96
(—CO ₂ C ₂ H ₅) ₂ (1.37 ml.)	3,5-Dimethyl-2- pyrryl-MgBr|| (3.62 g. 2,4-dimethylpyrrole)	Bis(3,5-dimethyl-2-pyrryl)gloxal	107

* *I.e.*, two moles of Grignard reagent per mole of ester.† *I.e.*, four moles of Grignard reagent per mole of ester.

‡ Dropwise addition of ester to filtered Grignard reagent solution.

§ Addition of filtered Grignard reagent solution to ester.

¶ Barbier synthesis.

|| Concerning the structures of pyrryl Grignard reagents see Nitrogen Heterocycles with "Active" Hydrogen, Chapter II.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂O₄R₂ (cont.)			
(—CO ₂ C ₂ H ₅) ₂ (22 g.)	(CH ₂) ₅ CHMgCl (120 g. C ₆ H ₁₁ Cl)	(CH ₂) ₅ CHCOCO ₂ C ₂ H ₅ (23 g.); HO[(CH ₂) ₅ CH] ₂ CCO ₂ C ₂ H ₅ (22 g.); HO[(CH ₂) ₅ CH] ₂ CCOCH(CH ₂) ₅ (1.8 g.)	305
(—CO ₂ C ₂ H ₅) ₂ (24.3 g.)	2-CH ₃ C ₆ H ₄ MgBr (28.5 g. C ₇ H ₇ Br)	2-CH ₃ C ₆ H ₄ CH(OH)CO ₂ C ₂ H ₅ (40%); HO(2-CH ₃ C ₆ H ₄) ₂ CCO ₂ C ₂ H ₅ (7 g., crude)	234
(—CO ₂ C ₂ H ₅) ₂	C ₆ H ₅ CH(CO ₂ Na)MgCl *	C ₆ H ₅ CH ₂ COCO ₂ C ₂ H ₅ (45.9%)	405
(—CO ₂ C ₂ H ₅) ₂ (2.75 ml.)	Hemopyrrol-MgBr (5.0 g. 2,3-dimethyl-4-ethylpyrrole)	Bis-(3-ethyl-4,5-dimethyl-2-pyrrol)glyoxal (0.8 g.)	107
(—CO ₂ C ₂ H ₅) ₂ (2.7 ml.)	Cryptopyrrol-MgBr (5.0 g. 2,4-dimethyl-3-ethylpyrrole)	Bis-(3,5-dimethyl-4-ethyl-2-pyrrol)glyoxal (0.72 g.); ethyl 3,5-dimethyl-4-ethyl-2-pyrrolglyoxalate	107
(—CO ₂ C ₂ H ₅) ₂ (36.5 g.)	<i>n</i> -C ₈ H ₁₇ MgBr (48.3 g. C ₈ H ₁₇ Br)	<i>n</i> -C ₈ H ₁₇ CH(OH)CO ₂ C ₂ H ₅ (25%)	234
(—CO ₂ C ₂ H ₅) ₂ (43.0 g.)	C ₆ H ₅ (CH ₃) ₂ CMgBr (?)† (58.3 g. C ₉ H ₁₁ Br)	[—C(CH ₃) ₂ C ₆ H ₅] ₂ (60%)†	234
(—CO ₂ C ₂ H ₅) ₂ (18 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (50 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ CH(OH)CO ₂ C ₂ H ₅ (12.5 g.); [2,4,6-(CH ₃) ₃ C ₆ H ₂ CO—] ₂ (1.5 g.); 2,4,6-(CH ₃) ₃ C ₆ H ₂ COCO ₂ C ₂ H ₅ (1.2 g.); [2,4,6-(CH ₃) ₃ C ₆ H ₂ —] ₂ (3.2 g.)‡	231

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

† It is possible that the product reported is attributable entirely to Wurtz reaction in the attempted preparation of the Grignard reagent. Brown, Mighton, and Senkus, *J. Org. Chem.*, 3, 62-75 (1938), report an unsuccessful attempt to prepare C₆H₅(CH₃)₂CMgCl by the action of magnesium on the appropriate chloride.

‡ According to Lapkin (233), this reaction also yields acetaldehyde, which would account for the formation of mandelate by a Meerwein-Ponndorf-Verley oxidation-reduction (see Alkoxide Reduction, Chapter VI).

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂O₄-R₂ (cont.)			
(—CO ₂ C ₂ H ₅) ₂ (0.25 mole)	(<i>n</i> -C ₄ H ₉) ₂ CHMgBr (?) (0.25 mole C ₉ H ₁₉ Br)	[(<i>n</i> -C ₄ H ₉) ₂ CH—] ₂ (30%); unidentified acid (2 g.)	234
(—CO ₂ C ₂ H ₅) ₂ (36 g.)	1-C ₁₀ H ₇ MgBr (52 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ CH(OH)CO ₂ C ₂ H ₅ (40%); (1-C ₁₀ H ₇ CO—) ₂ ; 1-C ₁₀ H ₇ CH(OH)CO-1-C ₁₀ H ₇	236
(—CO ₂ C ₂ H ₅) ₂ (21 g.)	2,3,4,6-(CH ₃) ₄ C ₆ HMgBr (30 g. C ₁₀ H ₁₃ Br)	2,3,4,6-(CH ₃) ₄ C ₆ HCH(OH)CO ₂ C ₂ H ₅ (35%)	236
(—CO ₂ C ₂ H ₅) ₂ (35 g.)	2,3,5,6-(CH ₃) ₄ C ₆ HMgBr (43 g. C ₁₀ H ₁₃ Br)	2,3,5,6-(CH ₃) ₄ C ₆ HCH(OH)CO ₂ C ₂ H ₅ (35%)	236
(—CO ₂ C ₂ H ₅) ₂ (35 g.)	(CH ₃) ₅ C ₆ MgBr (46 g. C ₁₁ H ₁₅ Br)	(CH ₃) ₅ C ₆ CH(OH)CO ₂ C ₂ H ₅ (30%)	236
(—CO ₂ C ₂ H ₅) ₂ (29.0 g.)	(C ₆ H ₅) ₂ CHMgCl (?) (40.4 g. C ₁₃ H ₁₁ Cl)	[(C ₆ H ₅) ₂ CH—] ₂ (90%)	234
(—CO ₂ <i>i</i> -C ₃ H ₇) ₂	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CH(OH)CO ₂ <i>i</i> -C ₃ H ₇ (30%)	231
(—CO ₂ <i>n</i> -C ₄ H ₉) ₂	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CH(OH)CO ₂ C ₂ H ₅ (40%)*	231
(—CO ₂ <i>n</i> -C ₄ H ₉) ₂ (40.4 g.)	1-C ₁₀ H ₇ MgBr (41.4 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ CH(OH)CO ₂ <i>n</i> -C ₄ H ₉ (40%)	234
(—CO ₂ <i>i</i> -C ₄ H ₉) ₂	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CH(OH)CO ₂ C ₂ H ₅ (40%)*	231
(—CO ₂ <i>i</i> -C ₄ H ₉) ₂	1-C ₁₀ H ₇ MgBr	1-C ₁₀ H ₇ CH(OH)CO ₂ C ₂ H ₅ (40%)	234
(—CO ₂ C ₆ H ₅) ₂ (30 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (25 g. C ₉ H ₁₁ Br)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCO ₂ C ₆ H ₅ (1.5 g., crude); C ₆ H ₅ OH (8.0 g.)	233
C₂O₅-R₂			
O(CO ₂ C ₂ H ₅) ₂ (9 g.)	C ₆ H ₅ MgBr (35 g. C ₆ H ₅ Br)	C ₆ H ₅ CO ₂ C ₂ H ₅ (54%); (C ₆ H ₅) ₃ COH (64%)	381
O(CO ₂ C ₄ H ₉) ₂	C ₆ H ₅ MgBr (23 g. C ₆ H ₅ Br)	C ₆ H ₅ CO ₂ C ₂ H ₅ (4.0 g.); (C ₆ H ₅) ₃ COH (6.3 g.)	381

* According to Lapkin (233), this reaction also yields butyraldehyde (Meerwein-Ponndorf-Verley oxidation-reduction, *q.v.*).

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₃O₂Cl₂-R			
Cl ₂ CHCO ₂ C ₂ H ₅	CH ₃ MgBr	Cl ₂ CH(CH ₃) ₂ COH	160
Cl ₂ CHCO ₂ C ₂ H ₅	CH ₃ MgI (2 equiv.)	Cl ₂ CHCOCH ₃ (ca. 4%); Cl ₂ CH(CH ₃) ₂ COH (65%)	175
C₂H₂O₂Br-R			
BrCH ₂ CO ₂ C ₂ H ₅	CH ₃ MgBr (4 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (32%)	171
C₂H₂O₂Cl-R			
ClCH ₂ CO ₂ CH ₃ (196 g.)	CH ₃ MgCl (120 g. Mg)	ClCH ₂ (CH ₃) ₂ COH (170–180 g., crude)	75
ClCH ₂ CO ₂ CH ₃	ClCH ₂ CO ₂ CH ₃ + Mg	ClCH ₂ COCH ₂ CO ₂ CH ₃	150
ClCH ₂ CO ₂ C ₂ H ₅	CH ₃ MgX*	ClCH ₂ (CH ₃) ₂ COH	224,160
ClCH ₂ CO ₂ C ₂ H ₅	CH ₃ MgBr (4 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (40%)	171
ClCH ₂ CO ₂ C ₂ H ₅	CH ₃ MgI (2 equiv.)	ClCH ₂ (CH ₃) ₂ COH (ca. 58%)	175
ClCH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	ClCH ₂ (C ₂ H ₅) ₂ COH; C ₂ H ₅ CH(OH)CH(C ₂ H ₅) ₂ (?)	110
ClCH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	ClCH ₂ (C ₂ H ₅) ₂ COH	410,91
ClCH ₂ CO ₂ C ₂ H ₅	ClCH ₂ CO ₂ C ₂ H ₅ + Mg	ClCH ₂ COCH ₂ COC ₂ H ₅ (56%); recovered ester	150
ClCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ CH(CO ₂ Na)MgCl†	ClCH ₂ [HO ₂ C(C ₆ H ₅)CH] ₂ COH (20%); C ₆ H ₅ CH ₂ CO ₂ H	405
ClCH ₂ CO ₂ C ₂ H ₅ (31 g.)	1-C ₁₀ H ₇ MgBr (52 g. C ₁₀ H ₇ Br)	ClCH ₂ CO-1-C ₁₀ H ₇ (4 g., crude; 1 g., pure)	233
ClCH ₂ CO ₂ <i>i</i> -C ₄ H ₉	ClCH ₂ CO ₂ <i>i</i> -C ₄ H ₉ + Mg	ClCH ₂ COCH ₂ CO ₂ <i>i</i> -C ₄ H ₉ (ca. 7 g. per mole ester)	150
C₂H₃O₃N-R			
H ₂ NOCCO ₂ C ₂ H ₅ (10 g.)	C ₆ H ₅ MgBr (81 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ COH (5 g.)	268
C₂H₃O₂R			
CH ₃ CO ₂ CH ₃	CH ₃ MgI	(CH ₃) ₃ COH (82%)	135,493
CH ₃ CO ₂ CH ₃	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>i</i> -C ₅ H ₁₁) ₂ COH	135

* X = Br, I.

† In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135–54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₅O₂R (cont.)			
CH ₃ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅) ₂ COH (67%)	80,307,379, 467
CH ₃ CO ₂ C ₂ H ₅	C ₂ H ₅ MgI	CH ₃ (C ₂ H ₅) ₂ COH	252
CH ₃ CO ₂ C ₂ H ₅	CH ₃ C≡CMgBr	CH ₃ (CH ₃ C≡C) ₂ COH	176,178
CH ₃ CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇) ₂ COH	149,333
CH ₃ CO ₂ C ₂ H ₅	<i>i</i> -C ₃ H ₇ MgCl (3 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)C(OH)CH ₂ CO- <i>i</i> -C ₃ H ₇ (65%); C ₃ H ₈ *	184
CH ₃ CO ₂ C ₂ H ₅	<i>i</i> -C ₃ H ₇ MgCl (3 equiv.)	CH ₃ CO- <i>i</i> -C ₃ H ₇ (60%); <i>i</i> -C ₃ H ₇ COCH=C(CH ₃)- <i>i</i> -C ₃ H ₇ ; C ₃ H ₈ †	184
CH ₃ CO ₂ C ₂ H ₅	<i>i</i> -C ₃ H ₇ MgCl (3 equiv.)	<i>i</i> -C ₃ H ₇ COCH=C(CH ₃)- <i>i</i> -C ₃ H ₇ (principal product); CH ₃ COCH ₂ CO- <i>i</i> -C ₃ H ₇ ; CH ₃ CO- <i>i</i> -C ₃ H ₇ ; C ₃ H ₈ †	184
CH ₃ CO ₂ C ₂ H ₅ (20 g.)	H ₂ C=CHC≡CMgBr	CH ₃ (H ₂ C=CHC≡C) ₂ COH (5 g.)	473
CH ₃ CO ₂ C ₂ H ₅	Pyrryl-MgBr	2-Acetylpyrrole (50-60%)	427
CH ₃ CO ₂ C ₂ H ₅ (176 g.)	ClCH ₂ CO ₂ C ₂ H ₅ (123 g.) +Mg(24 g.)	CH ₃ COCH ₂ CO ₂ C ₂ H ₅	393
CH ₃ CO ₂ C ₂ H ₅ (5.0 moles)	<i>n</i> -C ₄ H ₉ MgBr (10.6 moles C ₄ H ₉ Br)	CH ₃ (<i>n</i> -C ₄ H ₉) ₂ COH (64%); CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (3%)	458
CH ₃ CO ₂ C ₂ H ₅ (8.30 moles)	<i>n</i> -C ₄ H ₉ MgBr (17.25 moles C ₄ H ₉ Br)	CH ₃ (<i>n</i> -C ₄ H ₉) ₂ COH (79%)	74,462,332, 333
CH ₃ CO ₂ C ₂ H ₅	<i>i</i> -C ₄ H ₉ MgBr	CH ₃ (<i>i</i> -C ₄ H ₉) ₂ COH	149
CH ₃ CO ₂ C ₂ H ₅	<i>i</i> -C ₄ H ₉ MgBr	CH ₃ CO- <i>i</i> -C ₄ H ₉ ; CH ₃ (<i>i</i> -C ₄ H ₉)CHOH	383
CH ₃ CO ₂ C ₂ H ₅	<i>s</i> -C ₄ H ₉ MgBr	(CH ₃) ₂ CO; CH ₃ CO- <i>s</i> -C ₄ H ₉	327
CH ₃ CO ₂ C ₂ H ₅	<i>t</i> -C ₄ H ₉ MgCl	(CH ₃) ₂ CO (42%); (CH ₃) ₂ C=CHCOCH ₃ ; [(CH ₃) ₂ C=CH] ₂ CO; CH ₃ CO- <i>t</i> -C ₄ H ₉ ; CH ₃ CO ₂ CH(CH ₃)- <i>t</i> -C ₄ H ₉ ; CH ₃ COCH ₂ O- <i>t</i> -C ₄ H ₉	194,327

* Addition of Et₂O-ester solution to Grignard reagent solution; one hour reflux; hydrolysis with NH₄Cl or H₂SO₄; distillation at 14 mm.

† Addition of Et₂O-ester solution to Grignard reagent solution; one hour reflux; hydrolysis with NH₄Cl; distillation at barometric pressure.

‡ Addition of Et₂O-ester solution to Grignard reagent solution; one hour reflux; hydrolysis with H₂SO₄; distillation at barometric

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₃O₂R (cont.)			
CH ₃ CO ₂ C ₂ H ₅	H ₂ C(CH ₂ CH ₂ MgBr) ₂	1-Methylcyclohexanol (45%)	140
CH ₃ C ¹³ O ₂ C ₂ H ₅ (or CH ₃ C ¹⁴ CO ₂ C ₂ H ₅)	H ₂ C(CH ₂ CH ₂ MgBr) ₂	1-Methylcyclohexanol (60–70%)	490
CH ₃ CO ₂ C ₂ H ₅	<i>n</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>n</i> -C ₅ H ₁₁) ₂ COH (75%)	461
CH ₃ CO ₂ C ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ (<i>i</i> -C ₅ H ₁₁) ₂ COH (45%)	493,149
CH ₃ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ C=CH ₂ (80%)	400
CH ₃ CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl	CH ₃ (C ₆ H ₅ CH ₂) ₂ COH	421,426
CH ₃ CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl (1 equiv.)	CH ₃ COCH ₂ C ₆ H ₅ (2.7%); high-boiling alcohol (ca. 90%)	459
CH ₃ CO ₂ C ₂ H ₅	4-CH ₃ SC ₆ H ₄ MgBr	(4-CH ₃ SC ₆ H ₄) ₂ C=CH ₂	412
CH ₃ CO ₂ C ₂ H ₅ (20 g.)	<i>n</i> -C ₇ H ₁₅ MgBr (80 g. C ₇ H ₁₅ Br)	CH ₃ (<i>n</i> -C ₇ H ₁₅) ₂ COH (32 g.)	47
CH ₃ CO ₂ C ₂ H ₅	CH ₃ (<i>i</i> -C ₄ H ₉)CHCH ₂ MgBr	C ₂ H ₅ CH(CH ₃)CH ₂ CH(CH ₃)CH ₂ OH; CH ₃ (<i>i</i> - C ₄ H ₉)CH=CH ₂ ; <i>i</i> -C ₄ H ₉ (CH ₃) ₂ CH	433
CH ₃ CO ₂ C ₂ H ₅	(<i>i</i> -C ₃ H ₇) ₂ CHMgBr	"Secondary products only"	433
CH ₃ CO ₂ C ₂ H ₅	C ₆ H ₅ C≡CMgX	CH ₃ (C ₆ H ₅ C≡C) ₂ COH (80%)	399
CH ₃ CO ₂ C ₂ H ₅	Indolyl-MgBr	1-Acetylintole (2.8 g.); 3-acetylintole (trace)	348
CH ₃ CO ₂ C ₂ H ₅ (10 g.)	<i>n</i> -C ₈ H ₁₇ MgBr (48 g. C ₈ H ₁₇ Br)	CH ₃ (<i>n</i> -C ₈ H ₁₇) ₂ COH (10 g.)	47,339
CH ₃ CO ₂ C ₂ H ₅	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ OH; 2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₃ ; CH ₃ CO ₂ CH[C ₆ H ₂ -2,4,6-(CH ₃) ₃] ₂ (?)	235
CH ₃ CO ₂ C ₂ H ₅	(CH ₃) ₅ C ₆ MgBr	(CH ₃) ₆ C ₆ *; <i>t</i> -C ₄ H ₉ OH*; CH ₃ COC ₆ (CH ₃) ₅ (40%)	85,82,368
CH ₃ CO ₂ C ₂ H ₅ (3.5 ml.)	4-C ₆ H ₅ OC ₆ H ₄ MgBr (20.0 g. C ₁₂ H ₉ BrO)	(4-C ₆ H ₅ OC ₆ H ₄) ₂ C=CH ₂	412
CH ₃ CO ₂ CH ₂ COCH ₃	C ₂ H ₅ MgBr (1 equiv.)	Recovered ester (20%); CH ₃ (C ₂ H ₅) ₂ COH; HO(CH ₃)(C ₂ H ₅)CCH ₂ O ₂ CCH ₃	207
CH ₃ CO ₂ - <i>t</i> -C ₄ H ₉ (21.5 g., 0.185 mole)	<i>i</i> -C ₃ H ₇ MgBr (0.185 mole)	CH ₃ COCH ₂ - <i>t</i> -C ₄ H ₉ (6.1 g., 41%); "gas"	384

* Attributable to the use of methyl bromide as "entrainer" in the preparation of the Grignard reagent.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
$C_2H_5O_2R$ (<i>cont.</i>)			
$CH_3CO_2CH_2C_6H_5$	C_6H_5MgBr	$CH_3(C_6H_5)_2COH$; $(C_6H_5)_2C=CH_2$ (22%); $C_6H_5CH_2OH$	400,260
$CH_3CO_2CH(CO_2H)C_6H_5$	CH_3MgBr (2 equiv.)	$C_6H_5CH(OH)CO_2H$ (80.5%)	105
$CH_3CO_2CH(COCH_3)-n-C_5H_{11}$ (12.7 g.)	CH_3MgBr (15.0 g. Mg)	$t-C_4H_9OH$ ("a little"); $HO(CH_3)_2CCH(OH)-n-C_5H_{11}$ (6.5 g.)	496
$CH_3CO_2CH(COCH_3)C_6H_4-4-CH_3$ (17.0 g.)	CH_3MgBr (6.0 g. Mg)	$t-C_4H_9OH$; $HO(CH_3)_2CCH(OH)C_6H_4-4-CH_3$ (3.6 g.)	497
2-Methyl-3-acetoxy-5-isopropenyl- 2-cyclohexen-1-one	C_2H_5MgBr (2 equiv.)	$CH_3(C_2H_5)_2COH$; 2-methyl-3-ethyl-5-isopropenyl- 2-cyclohexen-1-one	425
9-Fluorenyl acetate	CH_3MgBr (6 equiv.)	9-Fluorenol (89.5%)	105
9-Acetoxymethylcarbazole (6.0 g.)	CH_3MgI (8.5 g. CH_3I)	9-Ethylcarbazole (73.9%)	285
9-Acetoxymethylcarbazole	C_2H_5MgBr	9- <i>n</i> -Propylcarbazole (67.0%)	285
9-Acetoxymethylcarbazole	C_6H_5MgBr	9-Benzylcarbazole (75.9%)	285
$CH_3CO_2CH(C_6H_5)_2$ (11 g.)	C_2H_5MgI (9 g. C_2H_5I)	$CH_3(C_2H_5)_2COH$ (1.5 g.); $[(C_6H_5)_2CH]_2O$ (3.0 g.); recovered ester; C_2H_4 ; C_2H_6	398
$CH_3CO_2CH(C_6H_5)_2$ (11 g.)	$n-C_3H_7MgI$ (18 g. C_3H_7I)	$[(C_6H_5)_2CH-]_2$ (1.4 g.); $[(C_6H_5)_2CH]_2O$ (1.2 g.); $(C_6H_5)_2CHOH$ (1.3 g.); $CH_3(n-C_3H_7)_2COH$ (2.5 g., 40%); oil; C_3H_6 ; C_3H_8	398
$CH_3CO_2CH(C_6H_5)_2$ (22 g.)	$n-C_4H_9MgI$ (37 g. C_4H_9I)	$[(C_6H_5)_2CH-]_2$ (6 g.); $(C_6H_5)_2CHOH$ (8.6 g.); $CH_3(n-C_4H_9)_2COH$ (7.0 g.); C_4H_8 ; C_4H_{10}	398
$CH_3CO_2CH(C_6H_5)_2$ (11 g.)	$i-C_5H_{11}MgI$ (10 g. $C_5H_{11}I$)	$CH_3(i-C_5H_{11})_2COH$ (50%); recovered ester	398
$CH_3CO_2CH(C_6H_5)_2$ (22 g.)	C_6H_5MgBr (32 g. C_6H_5Br)	$[(C_6H_5)_2CH]_2O$ (7.6 g.); $CH_3(C_6H_5)C=C(C_6H_5)_2$; recovered ester	398
9-Acetoxyanthracene (10 g.)	CH_3MgBr (0.4 mole)	9-Anthrol (attempted peroxidation yielded bianthrone)	186
9-Acetoxy-10-vinyanthracene (2 g.)	CH_3MgBr (0.1 mole)	10-Vinyl-9-anthrol (isolated as peroxide)	187
9-Acetoxy-10-ethylanthracene (5 g.)	CH_3MgBr (0.2 mole)	10-Ethyl-9-anthrol (isolated as peroxide, 3.4 g.)	186

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₃O₂-R (cont.)			
9-Acetoxy-10-propenylantracene (2.3 g.)	CH ₃ MgBr (0.05 mole)	10-Propenyl-9-anthrol (isolated as peroxide, 1.9 g.)	187
9-Acetoxy-10-(1-butenyl)anthracene (3 g.)	CH ₃ MgBr (0.1 mole)	10-(1-Butenyl)-9-anthrol (isolated as peroxide)	187
7-Acetoxy-1,2,3,4-tetrahydrobenz[<i>a</i>]anthracene (8.0 g.)	<i>n</i> -C ₄ H ₉ MgBr (14.8 g. C ₄ H ₉ Br)	1,2,3,4-Tetrahydrobenz[<i>a</i>]anthracen-7(12 <i>H</i>)-one (5.6 g., 82%)	104
CH ₃ CO ₂ C(C ₆ H ₅) ₃ (3.0 g.)	CH ₃ MgBr (1.2 g. Mg)	CH ₃ C(C ₆ H ₅) ₃ (69%)	105,9
9-Acetoxy-10-(β-isopropylvinyl)anthracene (2.5 g.)	CH ₃ MgBr (0.05 mole)	10-(β-Isopropylvinyl)-9-anthrol (isolated as peroxide, 2.4 g.)	187
3,4'-Ace-1,2-Benanthryl 10-acetate* (5.5 g.)	<i>n</i> -C ₄ H ₉ MgBr (9.0 g. C ₄ H ₉ Br)	3,4'-Ace-1,2-benzanthracen-10-ol† (90%, crude)	286
9-Acetoxy-10-phenylantracene (5 g.)	CH ₃ MgBr (0.15 mole)	10-Phenyl-9-anthrol (isolated as peroxide, 3.5 g.)	186
3-Acetoxy-17-cyano-Δ ^{5,16} -androstadiene (1.8 g.)	CH ₃ MgBr (5 g. Mg)	Δ ^{5,16} -Pregnadien-3-ol-20-one (1.26 g., 75%)	70
3-Acetoxy-17-cyano-Δ ^{5,16} -androstadiene	CH ₃ MgBr	17-Cyano-Δ ^{5,16} -androstadien-3-ol	70
3-Acetoxy-17-cyano-Δ ¹⁶ -androstene (900 mg.)	CH ₃ MgBr (2.5 g. Mg)	Δ ¹⁶ - <i>eso-allo</i> -Pregnen-3-ol-20-one (450 mg.)	69
(C₂H₃O₂)_x-R			
3,4-(CH ₃ CO ₂) ₂ C ₆ H ₃ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅) ₂ COH	90

* 7-Acetoxybenz[*k*]acephenanthrylene.† 7-Benz[*k*]acephenanthrylenol.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
$(C_2H_3O_2)_x-R$ (<i>cont.</i>)			
Triacetyl-L-arabonic acid lactone	C_6H_5MgBr (11 equiv.)	1,1-Diphenyl-L-arabitol* (15–16%); $CH_3(C_6H_5)_2COH$	316
Triacetyl-L-arabonic acid lactone (4.5 parts)	$C_6H_5CH_2MgCl$ (25.3 parts C_7H_7Cl)	1,1-Dibenzyl-L-arabitol† (<i>ca.</i> 15%); $CH_3(C_6H_5CH_2)_2COH$	316 316
Triacetyl-L-arabonic acid lactone	$4-CH_3C_6H_4MgBr$ (11 equiv.)	1,1-Di- <i>p</i> -tolyl-L-arabitol‡ (15%); $CH_3(4-CH_3C_6H_4)_2COH$	316
Triacetyl-D-xylosyl chloride	C_6H_5MgX (<i>ca.</i> 10 equiv.)	$CH_3(C_6H_5)_2COH$ (100%, crude); after reacetylation, triacetyl-D-xylopyranosylbenzene (86.6%, crude—25.0% α , 75.0% β)	169
Triacetyl-D-xylosyl chloride	$4-CH_3C_6H_4MgX$ (<i>ca.</i> 10 equiv.)	$CH_3(4-CH_3C_6H_4)_2COH$ (100%, crude); after reacetylation, <i>p</i> -(triacetyl-D-xylopyranosyl)toluene. (82.3%, crude—14.0% α , 86.0% β)	169
3,4,5- $(CH_3CO_2)_3C_6H_2CON(C_2H_5)_2$	C_2H_5MgBr	$CH_3(C_2H_5)_2COH$	90
Tetraacetyl-D-glucuronic acid γ -lactone	C_6H_5MgBr (12 equiv.)	1,1-Diphenyl-D-sorbitol § (10–12%); $CH_3(C_6H_5)_2COH$	315
Tetraacetyl-D-glucuronic acid γ -lactone	C_6H_5MgBr (13 equiv.)	1,1-Diphenyl-D-sorbitol§ (25%); $CH_3(C_6H_5)_2COH$	479
Tetraacetyl-D-glucuronic acid lactone (5.5 g.)	$C_6H_5CH_2MgCl$ (30 g. C_7H_7Cl)	1,1-Dibenzyl-D-sorbitol;† $CH_3(C_6H_5CH_2)_2COH$	314
Tetraacetyl-D-glucuronic acid lactone	$4-CH_3C_6H_4MgBr$ (13 equiv.)	1,1-Di- <i>p</i> -tolyl-D-sorbitol;‡ $CH_3(4-CH_3C_6H_4)_2COH$	314

* $HO(C_6H_5)_2C[CH(OH)]_3CH_2OH$.† $HO(C_6H_5CH_2)_2C[CH(OH)]_3CH_2OH$.‡ $HO(4-CH_3C_6H_4)_2C[CH(OH)]_3CH_2OH$.§ $HO(C_6H_5)_2C[CH(OH)]_4CH_2OH$.¶ $HO(C_6H_5CH_2)_2C[CH(OH)]_4CH_2OH$.‡ $HO(4-CH_3C_6H_4)_2C[CH(OH)]_4CH_2OH$.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
$(C_2H_3O_2)_xR$ (cont.)			
Tetraäcetyl-D-galactonic acid lactone	C_6H_5MgBr (14 equiv.)	1,1-Diphenyldulcitol* (30%); $CH_3(C_6H_5)_2COH$	480,314
Tetraäcetyl-D-galactonic acid lactone	$4-CH_3C_6H_4MgBr$ (14 equiv.)	1,1-Di- <i>p</i> -tolylldulcitol†; $CH_3(n-CH_3C_6H_4)_2COH$	314
Tetraäcetyl- α -D-glucosyl chloride	$i-C_3H_7MgX$ (ca. 12 equiv.)	$CH_3(i-C_3H_7)_2COH$ (50.8%, crude); unidentified syrup mixture	169
Tetraäcetyl- α -D-glucosyl chloride	$n-C_4H_9MgX$ (ca. 12 equiv.)	$CH_3(n-C_4H_9)_2COH$ (95.6%, crude); after reacetylation, 1-(tetraäcetyl-D-glucopyranosyl)butane (59.4%, crude)	169
Tetraäcetyl- α -D-glucosyl chloride (0.0136 mole)	C_6H_5MgBr (0.165 mole C_6H_5Br)	$CH_3(C_6H_5)_2COH$ (100%, crude); after reacetylation, tetraäcetyl-D-glucopyranosylbenzene (82%, crude—28.4% α , 71.6% β)	169
Tetraäcetyl- α -D-glucosyl chloride	$C_6H_5CH_2MgX$ (ca. 12 equiv.)	$CH_3(C_6H_5CH_2)_2COH$ (100%, crude); unidentified syrup mixture	169
Tetraäcetyl- α -D-glucosyl chloride	$4-CH_3C_6H_4MgBr$ (ca. 12 equiv.)	$CH_3(4-CH_3C_6H_4)_2COH$ (98.5%, crude); after reacetylation, <i>p</i> -(tetraäcetyl-D-glucopyranosyl)toluene (75.0%, crude—26.6% α , 73.4% β)	169
Tetraäcetyl- α -D-glucosyl chloride	$1-C_{10}H_7MgX$ (ca. 12 equiv.)	$CH_3(1-C_{10}H_7)_2COH$ (66%, crude); after reacetylation, 1-(tetraäcetyl-D-glucopyranosyl)naphthalene (65.0%, crude—33.3% α , 66.7% β)	169
Tetraäcetylglucose	CH_3MgI (2 equiv.)	$C_{14}H_{20}O_{10} \cdot 2CH_3MgI$ (regenerating tetraäcetylglucose upon hydrolysis)	108
Tetraäcetylfructose	C_2H_5MgI	$C_{14}H_{20}O_{10} \cdot 2C_2H_5MgI$ (regenerating tetraäcetylfructose upon hydrolysis)	116
Tetraäcetyl- α -methyl-glucoside	CH_3MgI (2 equiv.)	$C_{15}H_{21}O_9 \cdot 2CH_3MgI$	108
Pentaäcetyl- α -D-glucose	C_6H_5MgX (ca. 14 equiv.)	$CH_3(C_6H_5)_2COH$ (97.8%, crude); unidentified syrup mixture	169

* $HO(C_6H_5)_2C[CH(OH)]_4CH_2OH$.† $HO(4-CH_3C_6H_4)_2C[CH(OH)]_4CH_2OH$.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
(C₂H₃O₂)_x-R (cont.)			
Pentaäcetyl- α -D-glucose	C ₆ H ₅ MgX (ca. 14 equiv.)	CH ₃ (C ₆ H ₅) ₂ COH (89.3%, crude); unidentified syrup mixture	169
Octaäcetyllactose (2 g.)	CH ₃ MgI (from 8 g. CH ₃ I)	C ₂₈ H ₃₈ O ₁₉ ·2CH ₃ MgI (regenerating octaäcetyllactose upon hydrolysis)	116
C₂H₃O₃-R			
HOCH ₂ CO ₂ C ₂ H ₅ (10 g.)	C ₆ H ₅ MgBr (53 g. C ₆ H ₅ Br)	1,1-Diphenylepoxyethane (9 g., crude)	319
HOCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr (3 equiv.)	(C ₆ H ₅) ₂ C(OH)CH ₂ OH	200
HOCH ₂ CO ₂ C ₂ H ₅ (52 g.)	C ₆ H ₅ CH ₂ MgCl (260 g. C ₇ H ₇ Cl)	(C ₆ H ₅ CH ₂) ₂ C(OH)CH ₂ OH (70 g.)	420
C₂H₄O₂N-R			
H ₂ NCH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	H ₂ NCH ₂ C(C ₂ H ₅) ₂ OH (isolated as benzoyl deriv., 62%)	416
H ₂ NCH ₂ CO ₂ C ₂ H ₅ (from 10 g. hydrochloride)	C ₆ H ₅ MgBr (41 g. C ₆ H ₅ Br)	H ₂ NCH ₂ C(C ₆ H ₅) ₂ OH (6 g.); (C ₆ H ₅ —) ₂	317
H ₂ NCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	H ₂ NCH ₂ C(C ₆ H ₅) ₂ OH (60%)	416
C₂H₅O₂ClN-R			
HCl·H ₂ NCH ₂ CO ₂ C ₂ H ₅	CH ₃ MgI	H ₂ NCH ₂ C(CH ₃) ₂ OH	190
HCl·H ₂ NCH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	H ₂ NCH ₂ C(C ₂ H ₅) ₂ OH (24%)	416, 190
HCl·H ₂ NCH ₂ CO ₂ C ₂ H ₅ (23.3 g., 0.167 mole)	<i>n</i> -C ₃ H ₇ MgCl (68.7 g., 0.668 mole)	HCl·H ₂ NCH ₂ C(<i>n</i> -C ₃ H ₇) ₂ OH (15.8 g., 52.1%); gas (12.6 l.)*	134
HCl·H ₂ NCH ₂ CO ₂ C ₂ H ₅ (23.3 g., 0.167 mole)	<i>n</i> -C ₃ H ₇ MgCl (68.7 g., 0.668 mole)	HCl·H ₂ NCH ₂ C(<i>n</i> -C ₃ H ₇) ₂ OH (8.3 g., 27.3%); gas (10.0 l.)†	134

* Gradual (three hours) addition of ester to Grignard reagent solution; half-hour stirring; 1.0 hour reflux.

† Gradual (1.5 hour) addition of ester to Grignard reagent solution at -10 to -5°; 3.0 hours at -10°; warming to 30°.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₅O₂ClN-R (cont.)			
HCl·H ₂ NCH ₂ CO ₂ C ₂ H ₅ (23.3 g., 0.167 mole)	<i>n</i> -C ₃ H ₇ MgCl (137.3 g., 1.33 mole)	HCl·H ₂ NCH ₂ C(<i>n</i> -C ₃ H ₇) ₂ OH (22.8 g., 75.2%); gas 12.6 l., including 12.73 g. C ₃ H ₈)*	134
HCl·H ₂ NCH ₂ CO ₂ C ₂ H ₅ 23.3 g., 0.167 mole)	<i>n</i> -C ₃ H ₇ MgCl (137.3 g., 1.33 mole)	HCl·H ₂ NCH ₂ C(<i>n</i> -C ₃ H ₇) ₂ OH; HCl·H ₂ NCH ₂ CO- <i>n</i> -C ₃ H ₇ ; gas (18.9 l., including 19.78 g. C ₃ H ₈)†	134
HCl·H ₂ NCH ₂ CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgI	H ₂ NCH ₂ C(<i>n</i> -C ₃ H ₇) ₂ OH	190
HCl·H ₂ NCH ₂ CO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgI	H ₂ NCH ₂ C(<i>n</i> -C ₄ H ₉) ₂ OH	190
HCl·H ₂ NCH ₂ CO ₂ C ₂ H ₅ (23.3 g., 0.167 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.56 g., 1.33 mole)	Recovered ester (17.04 g.); gas (23.1 l., including 31.06 g. <i>i</i> -C ₄ H ₁₀)	134
HCl·H ₂ NCH ₂ CO ₂ C ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgI	H ₂ NCH ₂ C(<i>i</i> -C ₅ H ₁₁) ₂ OH	190
HCl·H ₂ NCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	H ₂ NCH ₂ C(C ₆ H ₅) ₂ OH (68%)	416,190
HCl·H ₂ NCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	H ₂ NCH ₂ C(CH ₂ C ₆ H ₅) ₂ OH (49.2%)	416,190
C₃O₂F₅-R			
C ₂ F ₅ CO ₂ CH ₃ (0.2-0.3 mole)	C ₂ H ₅ MgI (0.8-1.2 mole)	C ₂ F ₅ (C ₂ H ₅) ₂ COH (29.0%); C ₂ F ₅ (C ₂ H ₅)CHOH (66.0%)	515
C₃O₄Cl₂-R₂			
Cl ₂ C(CO ₂ C ₂ H ₅) ₂	CH ₃ MgBr	A chlorine-containing product b. 215-216°	237
C₃O₅-R₂			
OC(CO ₂ C ₂ H ₅) ₂	CH ₃ MgBr (5 equiv.)	OC[C(CH ₃) ₂ OH] ₂ ‡	237
OC(CO ₂ C ₂ H ₅) ₂	C ₂ H ₅ MgBr	H ₅ C ₂ O ₂ CCOC(C ₂ H ₅) ₂ OH ₃ § C ₆ H ₁₁ O, b. 140-150°; C ₇ H ₁₀ O ₃ , b. 190-200°	237

* Gradual (one and one-quarter hour) addition of Et₂O-ester suspension to stirred Grignard reagent solution; four hours stirring; one hour reflux.

† Gradual (one hour) addition of Et₂O-ester suspension to stirred Grignard reagent suspension; one and one-quarter hour stirring; two and one-half hours reflux.

‡ According to Lapkin and Golovkova (481), this product is probably HO(CH₃)(CH₃CO)CC(CH₃)₂OH.

§ According to Lapkin and Golovkova (481), this product is probably HO(C₂H₅)(C₂H₅CO)CCO₂C₂H₅.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃HO₄Cl-R₂			
HClC(CO ₂ C ₂ H ₅) ₂	CH ₃ MgBr	Gas evolution; ester recovered on hydrolysis	237
C₃HO₄Na-R₂			
NaHC(CO ₂ C ₂ H ₅) ₂	4-(CH ₂) ₄ CHC ₆ H ₄ CH ₂ CH ₂ MgBr	4-(CH ₂) ₄ CHC ₆ H ₄ (CH ₂) ₃ CO ₂ H	73
C₃H₂O₄-R₂			
H ₂ C(CO ₂ CH ₃) ₂ (20 g.)	C ₆ H ₅ MgBr (70 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH ₂ C(C ₆ H ₅) ₂ OH (15 g., crude)	444
H ₂ C(CO ₂ C ₂ H ₅) ₂ (16 g.)	CH ₃ MgI (36 g. CH ₃ I)	Most of ester recovered (by hydrolysis of enolate)	163
H ₂ C(CO ₂ C ₂ H ₅) ₂	C ₂ H ₅ MgI	(C ₂ H ₅) ₂ C=CHC(C ₂ H ₅) ₂ OH	436
H ₂ C(CO ₂ C ₂ H ₅) ₂ (20 g.)	C ₆ H ₅ MgBr (79 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH ₂ C(C ₆ H ₅) ₂ OH (14.9 g.)	444,96
H ₂ C(CO ₂ C ₂ H ₅) ₂ (0.25 mole)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (0.25 mole C ₉ H ₁₁ Br)	Recovered ester + C ₉ H ₁₂ (nearly quant.); product(s) b. (14 mm.) 165-195° (0.4 g.)	233
C₃H₃O₃-R			
CH ₃ COCO ₂ C ₂ H ₅ (29 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (50 g. C ₉ H ₁₁ Br)	HO(CH ₃)[2,4,6-(CH ₃) ₃ C ₆ H ₂]CCO ₂ C ₂ H ₅ (20%)	481
CH ₃ COCO ₂ C ₂ H ₅ (14.5 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (50.0 g. C ₉ H ₁₁ Br)	HO(CH ₃)[2,4,6-(CH ₃) ₃ C ₆ H ₂]CCO ₂ C ₂ H ₅ (50%)	481
C₃H₄O₂Br-R			
BrCH ₂ CH ₂ CO ₂ CH ₃ (320 g.)	CH ₃ MgCl (144 g. Mg)	BrCH ₂ CH ₂ (CH ₃) ₂ COH (270 g., crude)	75
CH ₃ CHBrCO ₂ C ₂ H ₅	C ₆ H ₅ CH(CO ₂ Na)MgCl*	CH ₃ CH(CO ₂ H)CH(C ₆ H ₅)CO ₂ C ₂ H ₅ (5%)	405
C₃H₄O₂Cl-R			
ClCH ₂ CH ₂ CO ₂ C ₂ H ₅	CH ₃ MgBr	ClCH ₂ CH ₂ (CH ₃) ₂ COH	160,324

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₄O₂Cl-R (cont.)			
ClCH ₂ CH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr (3 equiv.)	ClCH ₂ CH ₂ (C ₂ H ₅) ₂ COH (40%); four unidentified products	294
ClCH ₂ CH ₂ CO ₂ C ₂ H ₅ (42 ml.)	C ₂ H ₅ MgBr (57.2 ml. C ₂ H ₅ Br)	ClCH ₂ CH ₂ (C ₂ H ₅) ₂ COH (19-25 g.)	446,110
ClCH ₂ CH ₂ CO ₂ C ₂ H ₅ (41 g.)	<i>n</i> -C ₄ H ₉ MgBr (90 g. C ₄ H ₉ Br)	ClCH ₂ CH ₂ (<i>n</i> -C ₄ H ₉) ₂ COH (46 g.)	446
ClCH ₂ CH ₂ CO ₂ C ₂ H ₅ (68 g.)	C ₆ H ₅ MgBr (104.6 ml. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ C=CHCH ₂ Cl; C ₆ H ₅ COCH ₂ CH ₂ Cl	446
ClCH ₂ CH ₂ CO ₂ C ₂ H ₅ (42 ml.)	C ₆ H ₅ CH ₂ MgCl (77 ml. C ₇ H ₇ Cl)	ClCH ₂ CH ₂ (C ₆ H ₅ CH ₂) ₂ COH (35-46 g.)	446
CH ₃ CHClCO ₂ C ₂ H ₅	CH ₃ MgBr	CH ₃ CHCl(CH ₃) ₂ COH	160
CH ₃ CHClCO ₂ C ₂ H ₅ (40 g.)	C ₂ H ₅ MgBr (from 68 g. bromide)	CH ₃ CHCl(C ₂ H ₅) ₂ COH (37%, purified); unidentified products	294
C₃H₄O₂I-R			
ICH ₂ CH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr (3 equiv.)	ICH ₂ CH ₂ (C ₂ H ₅) ₂ COH	91
C₃H₅O₂-R			
C ₂ H ₅ CO ₂ CH ₃	<i>n</i> -C ₄ H ₉ MgBr	C ₂ H ₅ (<i>n</i> -C ₄ H ₉) ₂ COH (35%)	462
C ₂ H ₅ CO ₂ C ₂ H ₅ (200 g., ca. 2 moles)	C ₂ H ₅ MgBr (763 g., 7 moles C ₂ H ₅ Br)	(C ₂ H ₅) ₃ COH (765 g.)	59
C ₂ H ₅ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr (4 moles)	(C ₂ H ₅) ₃ COH (83%)	101,379
C ₂ H ₅ CO ₂ C ₂ H ₅	H ₂ C=CHCH ₂ MgBr	C ₂ H ₅ (H ₂ C=CHCH ₂) ₂ COH (66%)	162
C ₂ H ₅ CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	C ₂ H ₅ (<i>n</i> -C ₃ H ₇) ₂ COH (58%)	80,149
C ₂ H ₅ CO ₂ C ₂ H ₅	<i>i</i> -C ₃ H ₇ MgCl (2.75 equiv.)	C ₂ H ₅ CO- <i>i</i> -C ₃ H ₇ (48%); C ₃ H ₈ ; unidentified product(s)	184
C ₂ H ₅ CO ₂ C ₂ H ₅	Pyrryl-MgBr	2-Propionylpyrrole (50-60%)	427
C ₂ H ₅ CO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgCl	C ₂ H ₅ (<i>n</i> -C ₄ H ₉) ₂ COH (75%)	503
C ₂ H ₅ CO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgBr	C ₂ H ₅ (<i>n</i> -C ₄ H ₉) ₂ COH (73%)	80

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₅O₂-R (cont.)			
C ₂ H ₅ CO ₂ C ₂ H ₅	<i>s</i> -C ₄ H ₉ MgBr	(C ₂ H ₅) ₂ CO; C ₂ H ₅ CO- <i>s</i> -C ₄ H ₉	327
C ₂ H ₅ CO ₂ C ₂ H ₅	<i>t</i> -C ₄ H ₉ MgCl	(C ₂ H ₅) ₂ CO; C ₂ H ₅ CO- <i>t</i> -C ₄ H ₉ *	327
C ₂ H ₅ CO ₂ C ₂ H ₅ (102 g., 1.0 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.7 mole)	C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CHOH (23 g., 20%); C ₂ H ₅ COCH(CH ₃)CO ₂ C ₂ H ₅ (39 g., 50%) [†]	476
C ₂ H ₅ CO ₂ C ₂ H ₅	<i>t</i> -C ₄ H ₉ MgCl	C ₂ H ₅ CO ₂ CH(C ₂ H ₅)- <i>t</i> -C ₄ H ₉ (44.7%); (C ₂ H ₅) ₂ CO (trace); (C ₂ H ₅) ₂ C=C(CH ₃)COC ₂ H ₅ (trace) [‡]	194
C ₂ H ₅ CO ₂ C ₂ H ₅	<i>n</i> -C ₅ H ₁₁ MgBr	C ₂ H ₅ (<i>n</i> -C ₅ H ₁₁) ₂ COH (40%)	461
C ₂ H ₅ CO ₂ C ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr	C ₂ H ₅ (<i>i</i> -C ₅ H ₁₁) ₂ COH ("good yield")	149
C ₂ H ₅ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₂ H ₅ (C ₆ H ₅) ₂ COH	260
C ₂ H ₅ CO ₂ C ₂ H ₅	(CH ₂) ₅ CHMgCl	C ₂ H ₅ COCH(CH ₂) ₅ ; C ₂ H ₅ CH(OH)CH(CH ₂) ₅ ; C ₆ H ₁₂ ; C ₆ H ₁₀	433
C ₂ H ₅ CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ Cl + Mg	C ₂ H ₅ (C ₆ H ₅ CH ₂) ₂ COH ("good yield")	94
C ₂ H ₅ CO ₂ C ₂ H ₅ (2 ml.)	4-CH ₃ SC ₆ H ₄ MgBr (10 g. C ₇ H ₇ BrS)	(4-CH ₃ SC ₆ H ₄) ₂ C=CHCH ₃ (4 g.)	412
C ₂ H ₅ CO ₂ C ₂ H ₅ (15 g.)	<i>n</i> -C ₈ H ₁₇ MgBr (48 g. C ₈ H ₁₇ Br)	C ₂ H ₅ (<i>n</i> -C ₈ H ₁₇) ₂ COH (10 g.)	47
C ₂ H ₅ CO ₂ C ₂ H ₅	4-C ₆ H ₅ OC ₆ H ₄ MgBr	(4-C ₆ H ₅ OC ₆ H ₄) ₂ C=CHCH ₃	412
C ₂ H ₅ CO ₂ - <i>n</i> -C ₃ H ₇	C ₂ H ₅ MgBr	(C ₂ H ₅) ₃ COH	456
C₃H₅O₃-R			
CH ₃ OCH ₂ CO ₂ C ₂ H ₅	CH ₃ MgI	CH ₃ OCH ₂ (CH ₃) ₂ COH	322
CH ₃ CH(OH)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	CH ₃ CH(OH)C(C ₂ H ₅) ₂ OH	419
CH ₃ CH(OH)CO ₂ C ₂ H ₅ (30 g.)	C ₆ H ₅ MgBr (80 g. C ₆ H ₅ Br)	CH ₃ CH(OH)C(C ₆ H ₅) ₂ OH (22 g.)	390,408
CH ₃ CH(OH)CO ₂ C ₂ H ₅	2-CH ₃ C ₆ H ₄ MgBr	CH ₃ COCH(C ₆ H ₄ -2-CH ₃) ₂	408

* Reaction in ether "under usual conditions" or at high temperature in toluene.

[†] Addition of Grignard reagent solution to cooled, stirred Et₂O-ester solution; five days at room temperature.

[‡] Reaction at 95-98° [presumably in high-boiling solvent—see Petrov, Karasev, and Cheltzova (326)].

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₅O₃-R (<i>cont.</i>)			
CH ₃ CH(OH)CO ₂ C ₂ H ₅	4-CH ₃ C ₆ H ₄ MgBr	CH ₃ CH(OH)C(C ₆ H ₄ -4-CH ₃) ₂ OH	408
C₃H₆O₂N-R			
CH ₃ CH(NH ₂)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	CH ₃ CH(NH ₂)C(C ₂ H ₅) ₂ OH (isolated as benzoyl deriv., 52%)	416
CH ₃ CH(NH ₂)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	CH ₃ CH(NH ₂)C(C ₆ H ₅) ₂ OH (59%)	416
C₃H₇O₂ClN-R			
CH ₃ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	CH ₃ MgI (6 equiv.)	CH ₃ CH(NH ₂ ·HCl)C(CH ₃) ₂ OH (60-66%)	30
L(+)-CH ₃ CH(NHNA ₂ ·HCl)CO ₂ C ₂ H ₅ (10.3 g.)	CH ₃ MgI (57 g. CH ₃ I)	(+)-CH ₃ CH(NH ₂ ·HCl)C(CH ₃) ₂ OH	30
CH ₃ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	CH ₃ CH(NH ₂)C(C ₂ H ₅) ₂ OH (55%)	416
CH ₃ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	CH ₃ CH(NH ₂)C(C ₆ H ₅) ₂ OH (67%)	416
CH ₃ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (20 g.)	C ₆ H ₅ MgBr (245 g. C ₆ H ₅ Br)	CH ₃ CH(NH ₂)C(C ₆ H ₅) ₂ OH (20 g., crude)	275
D-CH ₃ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (15 g.)	C ₆ H ₅ MgBr (150 g. C ₆ H ₅ Br)	D-CH ₃ CH(NH ₂)C(C ₆ H ₅) ₂ OH (11 g.)	274
CH ₃ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl (9 equiv.)	CH ₃ CH(NH ₂)C(CH ₂ C ₆ H ₅) ₂ OH	274
CH ₃ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (5 g.)	4-CH ₃ C ₆ H ₄ MgBr (50 g. C ₇ H ₇ Br)	CH ₃ CH(NH ₂)C(C ₆ H ₄ -4-CH ₃) ₂ (3 g.)	272
D-CH ₃ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (5 g.)	4-CH ₃ C ₆ H ₄ MgBr (50 g. C ₇ H ₇ Br)	CH ₃ CH(NH ₂)C(C ₆ H ₄ -4-CH ₃) ₂ (5.5 g.)	272
C₄O₂F₇-R			
<i>n</i> -C ₃ F ₇ CO ₂ CH ₃ (0.2-0.3 mole)	C ₂ H ₅ MgI (0.8-1.2 mole)	<i>n</i> -C ₃ F ₇ (C ₂ H ₅) ₂ COH (12.5%); C ₂ H ₅ (<i>n</i> -C ₃ F ₇)CHOH (68.6%)	515
C₄H₂O₄-R₂			
(=CHCO ₂ CH ₃) ₂	C ₂ H ₅ MgBr (8 equiv.)	C ₂ H ₅ COCH ₂ CH(C ₂ H ₅)COC ₂ H ₅	447

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₂O₄-R₂ (cont.)			
(=CHCO ₂ CH ₃) ₂ (14.4 g.)	<i>n</i> -C ₄ H ₉ MgBr (8 equiv.)	<i>n</i> -C ₄ H ₉ COCH ₂ CH(<i>n</i> -C ₄ H ₉)CO- <i>n</i> -C ₄ H ₉ (9 g.); HO(<i>n</i> -C ₄ H ₉) ₂ CCH=CHCO- <i>n</i> -C ₄ H ₉	447
(=CHCO ₂ CH ₃) ₂ (10 g.)	C ₆ H ₅ MgBr (44 g. C ₆ H ₅ Br)	2,2,5,5-Tetraphenyl-2,5-dihydrofuran; unidentified product(s)	346
(=CHCO ₂ CH ₃) ₂ (7.25 g.)	C ₆ H ₅ CH ₂ MgCl (8 equiv.)	C ₆ H ₅ CH ₂ COCH ₂ CH(CH ₂ C ₆ H ₅)COCH ₂ C ₆ H ₅ (2.0 g.)	447
C₄H₂O₃-R₂			
HOCH=C(CO ₂ C ₂ H ₅) ₂	C ₂ H ₅ MgBr	C ₂ H ₅ CH=C(CO ₂ C ₂ H ₅) ₂	356
HOCH=C(CO ₂ C ₂ H ₅) ₂	C ₆ H ₅ MgBr (excess)	C ₆ H ₅ CH=C(CO ₂ C ₂ H ₅) ₂	356
C₄H₄O₃Cl₃-R			
DL-Cl ₃ CCH(OH)CH ₂ CO ₂ C ₂ H ₅ * (10 g.)	C ₆ H ₅ MgBr (40 g. C ₆ H ₅ Br)	DL-Cl ₃ CCH(OH)CH ₂ C(C ₆ H ₅) ₂ OH (9 g.)	64
C₄H₄O₄-R₂			
(—CH ₂ CO ₂ C ₂ H ₅) ₂	CH ₃ MgBr	[—CH ₂ C(CH ₃) ₂ OH] ₂	67
(—CH ₂ CO ₂ C ₂ H ₅) ₂ (44 g.)	CH ₃ MgI (142 g. CH ₃ I)	[—CH ₂ C(CH ₃) ₂ OH] ₂ (ca. 45%)	151,152,342, 436
(—CH ₂ CO ₂ C ₂ H ₅) ₂ (87 g.)	CH ₃ I (177 g.) + Mg (30 g.)†	γ-Hydroxy-γ-methylvaleric acid γ-lactone (57 g., 50%)	163
(—CH ₂ CO ₂ C ₂ H ₅) ₂ (87 g.)	C ₂ H ₅ Br (136 g.) + Mg (30 g.)†	Recovered ester; γ-hydroxy-γ-ethylcaproic acid γ-lactone (33 g., 46%)	163
(—CH ₂ CO ₂ C ₂ H ₅) ₂ (40 g.)	<i>n</i> -C ₄ H ₉ MgBr (137 g. C ₄ H ₉ Br)	[—CH ₂ C(<i>n</i> -C ₄ H ₉) ₂ OH] ₂ (45 g.)	337

* Similarly treated, the methyl ester of the levo acid yielded no crystalline product.

† Alternate additions of Et₂O-halide-ester solution and Mg to reacting Mg (10 g.) and halide (10 g.); one hour stirring; overnight

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₄O₄-R₂ (cont.)			
(—CH ₂ CO ₂ C ₂ H ₅) ₂	C ₆ H ₅ MgBr	[—CH ₂ C(C ₆ H ₅) ₂ OH] ₂ (ca. quant.)*	96,2,437
(—CH ₂ CO ₂ C ₂ H ₅) ₂	C ₆ H ₅ MgBr	2,2,5,5-Tetraphenyltetrahydrofuran†	2
(—CH ₂ CO ₂ C ₂ H ₅) ₂	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	Recovered ester + (CH ₃) ₃ C ₆ H ₃ (nearly quant.)	233
C₄H₄O₅-R₂			
(-)-H ₃ CO ₂ CCH ₂ CH(OH)CO ₂ CH ₃	C ₆ H ₅ MgBr	No identifiable product	64
C₄H₄O₆-R₂			
D-[—CH(OH)CO ₂ CH ₃] ₂ (20 g.)	C ₆ H ₅ MgBr (160 g. C ₆ H ₅ Br)	D-[—CH(OH)C(C ₆ H ₅) ₂ OH] ₂	113
C₄H₅O₂-R			
(CH ₂) ₂ CHCO ₂ C ₂ H ₅	CH ₃ MgBr	(CH ₂) ₂ CH(CH ₃) ₂ COH	66
(CH ₂) ₂ CHCO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	(CH ₂) ₂ CH(C ₂ H ₅) ₂ COH	66
CH ₃ CH=CHCO ₂ C ₂ H ₅	CH ₃ MgBr	CH ₃ CH=CH(CH ₃) ₂ COH (ca. 50%); i-C ₄ H ₉ CO ₂ C ₂ H ₅ (?)	439
CH ₃ CH=CHCO ₂ C ₂ H ₅	CH ₃ MgBr	CH ₃ CH=CH(CH ₃) ₂ COH (36%)	19
H ₂ C=C(CH ₃)CO ₂ C ₂ H ₅	CH ₃ MgI (2 equiv.)	H ₂ C=C(CH ₃)C(CH ₃) ₂ OH; CH ₃ CH ₂ CH(CH ₃)COCH ₃	49,89
H ₂ C=C(CH ₃)CO ₂ C ₂ H ₅	CH ₃ MgI (2 equiv.)	H ₂ C=C(CH ₃)C(CH ₃) ₂ OH; [H ₂ C=C(CH ₃)—] ₂	49,89
H ₂ C=C(CH ₃)CO ₂ C ₂ H ₅	C ₂ H ₅ MgI (2 equiv.)	H ₂ C=C(CH ₃)C(C ₂ H ₅) ₂ OH	49,89
C₄H₅O₄N-R₂			
L-H ₂ NCH(CO ₂ C ₂ H ₅)CH ₂ CO ₂ C ₂ H ₅	CH ₃ MgI	HO(CH ₃) ₂ CCH(NH ₂)CH ₂ C(CH ₃) ₂ OH	188,189
L-H ₂ NCH(CO ₂ C ₂ H ₅)CH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	HO(C ₂ H ₅) ₂ CCH(NH ₂)CH ₂ C(C ₂ H ₅) ₂ OH	188
L-H ₂ NCH(CO ₂ C ₂ H ₅)CH ₂ CO ₂ C ₂ H ₅	n-C ₃ H ₇ MgI	HO(n-C ₃ H ₇) ₂ CCH(NH ₂)CH ₂ C(n-C ₃ H ₇) ₂ OH	188

* Dropwise addition of Et₂O-ester solution to Grignard reagent solution; standing at room temperature.

† Addition of ester to boiling Grignard reagent solution.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₅O₄N-R₂ (cont.)			
L-H ₂ NCH(CO ₂ C ₂ H ₅)CH ₂ CO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgI	HO(<i>n</i> -C ₄ H ₉) ₂ CCH(NH ₂)CH ₂ C(<i>n</i> -C ₄ H ₉) ₂ OH	188
L-H ₂ NCH(CO ₂ C ₂ H ₅)CH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	HO(C ₆ H ₅) ₂ CCH(NH ₂)CH ₂ C(C ₆ H ₅) ₂ OH	188,189
H ₂ NCH(CO ₂ C ₂ H ₅)CH ₂ CO ₂ C ₂ H ₅ (10 g.)	C ₆ H ₅ MgBr (50 g., C ₆ H ₅ Br)	HO(C ₆ H ₅) ₂ CCH(NH ₂)CH ₂ C(C ₆ H ₅) ₂ OH (60-70%)	320
C₄H₆O₂Cl-R			
Cl(CH ₂) ₃ CO ₂ CH ₃ (200 g.)	CH ₃ MgCl (4 moles)	Cl(CH ₂) ₃ (CH ₃) ₂ COH (200 g., crude)	75
Cl(CH ₂) ₃ CO ₂ C ₂ H ₅	CH ₃ MgBr	Cl(CH ₂) ₃ (CH ₃) ₂ COH	158,160,324
Cl(CH ₃) ₂ CCO ₂ C ₂ H ₅	CH ₃ MgBr	<i>t</i> -C ₄ H ₉ C(CH ₃) ₂ OH	157
C₄H₇O₂-R			
<i>n</i> -C ₃ H ₇ CO ₂ CH ₃	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₄ H ₉) ₂ COH (70%)	462
<i>n</i> -C ₃ H ₇ CO ₂ CH ₃	C ₆ H ₅ MgBr	<i>n</i> -C ₃ H ₇ (C ₆ H ₅) ₂ COH (yielding 80-90% olefin)	377
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	CH ₃ MgX (2 equiv.)	<i>n</i> -C ₃ H ₇ (CH ₃) ₂ COH (80-85%); corresponding olefin (ca. 1%)	259,252,467
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	<i>n</i> -C ₃ H ₇ (C ₂ H ₅) ₂ COH (61%)	80,149
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	C ₂ H ₅ MgX (2 equiv.)	<i>n</i> -C ₃ H ₇ (C ₂ H ₅) ₂ COH (80-85%); corresponding olefin (ca. 1%)	259
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgCl	(<i>n</i> -C ₃ H ₇) ₃ COH (69%); (<i>n</i> -C ₃ H ₇) ₂ CO (6%)	194
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	(<i>n</i> -C ₃ H ₇) ₃ COH ("good yield")	149
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	Pyrryl-MgBr	2-Butyrylpyrrole (50-60%)	427
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₄ H ₉) ₂ COH (73%)	80
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	<i>s</i> -C ₄ H ₉ MgBr	(<i>n</i> -C ₃ H ₇) ₂ CO; <i>n</i> -C ₃ H ₇ CO- <i>s</i> -C ₄ H ₉	327
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	<i>t</i> -C ₄ H ₉ MgCl	(<i>n</i> -C ₃ H ₇) ₂ CO; <i>n</i> -C ₃ H ₇ CO- <i>t</i> -C ₄ H ₉ ; unidentified product(s)	335,327
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₅ H ₁₁) ₂ COH (58%)	461
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₅ H ₁₁) ₂ COH ("good yield")	149

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₇O₂-R (cont.)			
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	<i>n</i> -C ₃ H ₇ (C ₆ H ₅) ₂ COH (60%)	266,260
<i>n</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl	<i>n</i> -C ₃ H ₇ (C ₆ H ₅ CH ₂) ₂ COH (yielding 61.1% olefin)	341
<i>i</i> -C ₃ H ₇ CO ₂ C ₂ H ₅	<i>i</i> -C ₃ H ₇ MgBr	(<i>i</i> -C ₃ H ₇) ₂ CHOH; C ₃ H ₆	404
<i>i</i> -C ₃ H ₇ CO ₂ C ₂ H ₅ (22 g., 0.19 mole)	2,4,6-(CH ₃) ₃ C ₆ H ₄ MgBr (0.19 mole)	<i>i</i> -C ₃ H ₇ CO(CH ₃) ₂ CCO ₂ C ₂ H ₅ (4.7 g., 26.5%)	396
<i>i</i> -C ₃ H ₇ CO- <i>trans</i> -C ₄ H ₉	<i>i</i> -C ₃ H ₇ MgBr	Recovered ester (45%); no gas evolution	384
C₄H₇O₃-R			
C ₂ H ₅ OCH ₂ CO ₂ C ₂ H ₅	RMgX*	C ₂ H ₅ OCH ₂ CH ₂ OH (ca. 60%)	31
C ₂ H ₅ OCH ₂ CO- <i>n</i> -C ₃ H ₇	H ₂ C=CHCH ₂ MgBr	C ₂ H ₅ OCH ₂ (H ₂ C=CHCH ₂) ₂ COH (90%)	162
HO(CH ₃) ₂ CCO ₂ CH ₃ (140 g.)	C ₂ H ₅ MgBr (500 g. C ₂ H ₅ Br)	HO(CH ₃) ₂ CC(C ₂ H ₅) ₂ OH (72%)	280
HO(CH ₃) ₂ CCO ₂ CH ₃	<i>n</i> -C ₃ H ₇ MgBr (4 equiv.)	HO(CH ₃) ₂ CC(<i>n</i> -C ₃ H ₇) ₂ OH; HO(CH ₃) ₂ CCH(<i>n</i> -C ₃ H ₇)OH; C ₃ H ₆	280
HO(CH ₃) ₂ CCO ₂ CH ₃ (59 g.)	<i>n</i> -C ₄ H ₉ MgBr (274 g. C ₄ H ₉ Br)	HO(CH ₃) ₂ CC(<i>n</i> -C ₄ H ₉) ₂ OH (56%); HO(CH ₃) ₂ CCH(<i>n</i> -C ₄ H ₉)OH (total yield glycols, ca. 80 g.); C ₄ H ₈	280
HO(CH ₃) ₂ CCO ₂ CH ₃	C ₆ H ₅ MgBr (4 equiv.)	HO(CH ₃) ₂ CC(C ₆ H ₅) ₂ OH (91%)	280
HO(CH ₃) ₂ CCO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4 equiv.)	HO(CH ₃) ₂ CC(<i>n</i> -C ₄ H ₉) ₂ OH (45%); HO(CH ₃) ₂ CCH(<i>n</i> -C ₄ H ₉)OH; <i>n</i> -C ₄ H ₉ OH; recovered ester	281
HO(CH ₃) ₂ CCO ₂ C ₂ H ₅	<i>n</i> -C ₅ H ₁₁ MgBr	HO(CH ₃) ₂ CC(<i>n</i> -C ₅ H ₁₁) ₂ OH; "a hydrocarbon" (chief product)	47
HO(CH ₃) ₂ CCO ₂ C ₂ H ₅ (14 g.)	<i>n</i> -C ₇ H ₁₅ MgBr	C ₁₈ H ₃₄ (22 g.)	47
HO(CH ₃) ₂ CCO ₂ C ₂ H ₅ (13.2 g.)	<i>n</i> -C ₁₂ H ₂₅ MgBr	<i>n</i> -C ₁₂ H ₂₆ (10 g.); C ₂₈ H ₅₄ (21 g.)	47
C₄H₇O₅-R			
HOCH ₂ [CH(OH)] ₂ CO ₂ C ₂ H ₅ (5 g.)	C ₆ H ₅ MgBr (4 equiv.)	HOCH ₂ [CHOH] ₂ C(C ₆ H ₅) ₂ OH (4.4 g., 42%)	321

* R = CH₃, C₂H₅, H₂C=CHCH₂, *n*-C₃H₇, *i*-C₄H₉, *i*-C₅H₁₁, C₆H₅.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₈O₃ClN₂-R			
HCl·H ₂ NCH ₂ CONHCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	H ₂ NCH ₂ CONHCH ₂ C(C ₆ H ₅) ₂ OH (66%)	417
C₄H₉O₂ClN-R			
C ₂ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (1.68 g.)	4-CH ₃ OC ₆ H ₄ MgBr (11.22 g. C ₇ H ₇ BrO)	C ₂ H ₅ CH(NH ₂)C(C ₆ H ₄ -4-OCH ₃) ₂ OH (2.15 g., 64%)	388
C₅H₃O₂S-R			
Ethyl 2-thiophenecarboxylate	2-Thienyl-MgBr	Tri- α -thienylmethanol (isolated as perchlorate)	371
C₅H₃O₃-R			
Ethyl furoate	CH ₃ Mgl	Unstable red-colored liquid	147
Ethyl furoate	C ₂ H ₅ Mgl	α -Furyldiethylmethanol	147
Ethyl furoate (8.5 g.)	C ₆ H ₅ MgBr (37.5 g. C ₆ H ₅ Br)	α -Furyldiphenylmethanol (9.2 g.)	435,147
Ethyl furoate	C ₆ H ₅ CH ₂ MgCl	α -Furyldibenzylmethanol	147
Ethyl furoate (7.0 g.)	4-C ₆ H ₅ C ₆ H ₄ MgBr (23.3 g. C ₁₂ H ₉ Br)	α -Furyldi- <i>p</i> -biphenylmethanol (70%)	114
C₅H₄O₃N-R			
Ethyl 5-methyl-3-isoxazolecarboxylate (60 g.)	CH ₃ Mgl (137 g. CH ₃ I)	2-(5-methyl-3-isoxazolyl)-2-propanol (34 g.)	350
C₅H₄O₄-R₂			
CH ₃ CH=C(CO ₂ C ₂ H ₅) ₂ (30 g., 0.16 mole)	1-C ₁₀ H ₇ CH ₂ MgCl (35 g., 0.21 mole C ₁₁ H ₉ Cl)	CH ₃ (1-C ₁₀ H ₇ CH ₂)CHCH(CO ₂ C ₂ H ₅) ₂ (22 g., 42%)	360
CH ₃ CH=C(CO ₂ C ₂ H ₅) ₂ (30 g., 0.16 mole)	1-C ₁₀ H ₇ CH ₂ MgCl (35 g., 0.21 mole C ₁₁ H ₉ Cl) + CdCl ₂ (36 g., 0.20 mole)	CH ₃ (1-C ₁₀ H ₇ CH ₂)CHCH(CO ₂ C ₂ H ₅) ₂ (60%)	360

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₅O₂-R			
H ₂ C=CHCH=CHCO ₂ C ₂ H ₅	C ₆ H ₅ MgBr (4 equiv.)	H ₂ C=CHCH(C ₆ H ₅)CH ₂ COC ₆ H ₅ (75%); unidentified product(s) (25%)	214
C₅H₅O₃-R			
C ₂ H ₅ C(=CO)CO ₂ C ₂ H ₅ (11 g., 0.077 mole)	C ₆ H ₅ MgBr (0.2 mole)	C ₂ H ₅ (C ₆ H ₅ CO)C=C(C ₆ H ₅) ₂ (2.5 g.); C ₂ H ₅ (C ₆ H ₅ CO)CHCO ₂ C ₂ H ₅ (5 ml.)	170
C ₂ H ₅ C(=CO)CO ₂ C ₂ H ₅ (8.5 g., 0.06 mole)	C ₆ H ₅ MgBr (0.06 mole)	C ₂ H ₅ (C ₆ H ₅ CO)CHCO ₂ C ₂ H ₅ (6.0 g.) <i>n</i> -C ₃ H ₇ COC ₆ H ₅ (<2.0 g.)	170
C₅H₅O₃BrCl-R			
C ₂ H ₅ CBBr(COCl)CO ₂ C ₂ H ₅ (8 g.)	C ₆ H ₅ MgBr (13 g. C ₆ H ₅ Br)	C ₂ H ₅ (C ₆ H ₅ CO)C=C(C ₆ H ₅) ₂ (0.1 g.)	170
C₅H₅O₄Br-R₂			
C ₂ H ₅ CBBr(CO ₂ C ₂ H ₅) ₂	C ₆ H ₅ MgBr	[C ₂ H ₅ (H ₅ C ₂ O ₂ C) ₂ C—] ₂ ; C ₆ H ₅ Br	361
C ₂ H ₅ CBBr(CO ₂ C ₂ H ₅) ₂	C ₁₀ H ₁₇ MgCl*	[C ₂ H ₅ (H ₅ C ₂ O ₂ C) ₂ C—] ₂ ; pinene hydrobromide	361
C ₂ H ₅ CBBr(CO ₂ C ₂ H ₅) ₂	"Bornyl-MgCl"	[C ₂ H ₅ (H ₅ C ₂ O ₂ C) ₂ C—] ₂ ; bornyl bromide	361
C₅H₆O₂N-R			
NC(C ₂ H ₅)CHCO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	(C ₂ H ₅ CO) ₂ CHC ₂ H ₅ (25-30%)	261
NC(C ₂ H ₅)CHCO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅ CO) ₂ CHC ₂ H ₅ (60%)	261
C₅H₆O₄-R₂			
H ₂ C(CH ₂ CO ₂ C ₂ H ₅) ₂ (64 g.)	CH ₃ MgI (270 g. CH ₃ I)	H ₂ C[CH ₂ C(CH ₃) ₂ OH] ₂ (30 g. monohydrate, 20 g. anhydr.)	301,474
H ₂ C(CH ₂ CO ₂ C ₂ H ₅) ₂	CH ₃ MgBr	H ₂ C[CH ₂ C(CH ₃) ₂ OH] ₂	67
C ₂ H ₅ CH(CO ₂ C ₂ H ₅) ₂ (19 g.)	CH ₃ MgI (36 g. CH ₃ I)	HO(CH ₃) ₂ CCH(C ₂ H ₅)CO ₂ C ₂ H ₅ (5 g., crude)	163

* From (+)- α -pinene hydrochloride.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₆O₄-R₂ (cont.)			
(CH ₃) ₂ C(CO ₂ C ₂ H ₅) ₂	CH ₃ MgI	(CH ₃) ₂ C[C(CH ₃) ₂ OH]; HO(CH ₃) ₂ CC(CH ₃) ₂ CO ₂ C ₂ H ₅	387
(CH ₃) ₂ C(CO ₂ C ₂ H ₅) ₂ (19 g.)	CH ₃ MgI (36 g. CH ₃ I)	HO(CH ₃) ₂ CC(CH ₃) ₂ CO ₂ C ₂ H ₅ (7 g., crude); recovered ester (9 g.)	163
(CH ₃) ₂ C(CO ₂ C ₂ H ₅) ₂	<i>n</i> -C ₃ H ₇ MgCl	(CH ₃) ₂ C[CH(OH)- <i>n</i> -C ₃ H ₇] ₂ ; (<i>n</i> -C ₃ H ₇) ₃ COH; (CH ₃) ₂ CHCO ₂ C ₂ H ₅ ; (<i>n</i> -C ₃ H ₇) ₂ CO; (<i>n</i> -C ₃ H ₇) ₂ CHOH; C ₃ H ₆ ; C ₃ H ₈ ; other products	238
(CH ₃) ₂ C(CO ₂ C ₂ H ₅) ₂	<i>n</i> -C ₃ H ₇ MgBr	(<i>n</i> -C ₃ H ₇) ₂ CHOH; (<i>n</i> -C ₃ H ₇) ₃ COH; (CH ₃) ₂ C[CH(OH)- <i>n</i> -C ₃ H ₇] ₂	238
C₅H₆O₅-R₂			
L-H ₃ CO ₂ CCH(OCH ₃)CH ₂ CO ₂ CH ₃ (10 g.)	CH ₃ MgI (10 g. Mg)	HO(CH ₃) ₂ CCH(OCH ₃)CH ₂ C(CH ₃) ₂ OH; C ₉ H ₁₈ O ₂ (dehydr'n product)	345
L-H ₃ CO ₂ CCH(OCH ₃)CH ₂ CO ₂ CH ₃ (30 g.)	C ₆ H ₅ MgBr (215 g. C ₆ H ₅ Br)	2,2,5,5-Tetraphenyl-2,5-dihydrofuran (<i>ca.</i> 36 g.); "triphenylbutyrolactone", m. 160-161°	346
C₅H₇O₂-R			
(CH ₃) ₂ C=CHCO ₂ C ₂ H ₅	CH ₃ MgI (2 equiv.)	(CH ₃) ₂ C=CHC(CH ₃) ₂ OH; (CH ₃) ₂ C=CHC(CH ₃)=CH ₂ ; (CH ₃) ₃ CCH ₂ COCH ₃ (?)	49,89
(CH ₂) ₃ CHCO ₂ C ₂ H ₅ (24 g.)	C ₂ H ₅ MgI	(CH ₂) ₃ CHC(C ₂ H ₅) ₂ OH (22 g.)	202
C₅H₇O₃-R			
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅ (130.2 g.)	CH ₃ MgI (142.0 g. CH ₃ I)	γ,γ-Dimethylbutyrolactone (63.7 g., 62%)	504
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr (3 equiv.)	HO(CH ₃)(C ₂ H ₅)C(CH ₂) ₂ C(C ₂ H ₅) ₂ OH (63%)	138,139
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅	CH ₃ C≡CMgBr	HO(CH ₃)(CH ₃ C≡C)C(CH ₂) ₂ C(C≡CCCH ₃) ₂ OH	176
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅ (212 g.)	<i>n</i> -C ₃ H ₇ MgBr (207 g. C ₃ H ₇ Br)	γ-Methyl-γ- <i>n</i> -propylbutyrolactone (157.6 g., 73.3%)	77

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₇O₃-R (cont.)			
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr (3 equiv.)	HO(CH ₃)(<i>i</i> -C ₅ H ₁₁)C(CH ₂) ₂ C(<i>i</i> -C ₅ H ₁₁) ₂ OH	138
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅ (2 moles)	<i>n</i> -C ₆ H ₁₃ MgCl (2 moles C ₆ H ₁₃ Cl)	γ-Methyl-γ-decanolactone (103.2 g., 28%); recovered ester (25.1 g.)	112
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅ (2 moles)	<i>n</i> -C ₆ H ₁₃ MgBr (2 moles C ₆ H ₁₃ Br)	γ-Methyl-γ-decanolactone (113 g., 31%)	112
CH ₃ CO(CH ₂) ₂ CO ₂ C ₂ H ₅ (26.0 g.)	<i>n</i> -C ₁₀ H ₂₁ MgBr (44.2 g. C ₁₀ H ₂₁ Br)	γ-Methyl-γ- <i>n</i> -decylbutyrolactone (36.4 g., 84.4%)	77
C₅H₇O₄N-R₂			
D-H ₅ C ₂ O ₂ C(CH ₂) ₂ CH(NH ₂)CO ₂ C ₂ H ₅	CH ₃ MgI	2-[α'-(α-Pyrrolidonyl)]-2-propanol	188
D-H ₅ C ₂ O ₂ C(CH ₂) ₂ CH(NH ₂)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	3-[α'-(α-Pyrrolidonyl)]-3-pentanol	188
D-H ₅ C ₂ O ₂ C(CH ₂) ₂ CH(NH ₂)CO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgI	5-[α'-(α-Pyrrolidonyl)]-5-nonanol	188
D-H ₅ C ₂ O ₂ C(CH ₂) ₂ CH(NH ₂)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	α'-(α-Pyrrolidonyl)diphenylmethanol	188,189
D-H ₅ C ₂ O ₂ C(CH ₂) ₂ CH(NH ₂)CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl	1,3-Diphenyl-2-[α'-(α-pyrrolidonyl)]-2-propanol	188
C₅H₈O₂Br-R			
Br(CH ₂) ₄ CO ₂ CH ₃ (120 g.)	CH ₃ MgBr (50 g. Mg)	Br(CH ₂) ₄ C(CH ₃) ₂ OH (ca. 140 g., crude)	75
C₅H₈O₂Cl-R			
(CH ₃) ₂ CClCH ₂ CO ₂ C ₂ H ₅	CH ₃ MgBr	(CH ₃) ₂ CClCH ₂ C(CH ₃)=CH ₂ ; (CH ₃) ₂ CClCH ₂ C(CH ₃) ₂ OH	237,112
C₅H₈O₂N-R			
L-Proline ethyl ester*	C ₂ H ₅ MgBr	3-α-Pyrrolidyl-3-pentanol	193
L-Proline ethyl ester*	C ₆ H ₅ MgBr	α-Pyrrolidyl-diphenylmethanol	193

* L-2-Carboxypyrrolidine.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₈O₃N-R			
L-Hydroxyproline ethyl ester hydrochloride*	C ₆ H ₅ MgBr	4-Hydroxy-2-pyrrolidyl diphenylmethanol	193
C₅H₉O₂-R			
<i>n</i> -C ₄ H ₉ CO ₂ CH ₃	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₄ H ₉ (<i>n</i> -C ₃ H ₇) ₂ COH (37%)	462
<i>n</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	CH ₃ MgBr	<i>n</i> -C ₄ H ₉ (CH ₃) ₂ COH	161,298
<i>n</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	C ₂ H ₅ MgCl	<i>n</i> -C ₄ H ₉ (C ₂ H ₅) ₂ COH (30%)	462
<i>n</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	<i>n</i> -C ₄ H ₉ (C ₂ H ₅) ₂ COH (69%)	80,414
<i>n</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₄ H ₉ (<i>n</i> -C ₅ H ₁₁) ₂ COH (59%)	461
<i>n</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ C=CH- <i>n</i> -C ₃ H ₇	224
<i>i</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	CH ₃ MgI	<i>i</i> -C ₄ H ₉ (CH ₃) ₂ COH (80%)	79,23
<i>i</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	C ₂ H ₅ MgX (2 equiv.)	<i>i</i> -C ₄ H ₉ (C ₂ H ₅) ₂ COH (80-85%); corresponding olefin (<i>ca.</i> 1%)	259
<i>i</i> -C ₄ H ₉ CO ₂ C ₂ H ₅ (16.1 g.)	H ₂ C=CHCH ₂ Br (30 g.) + Mg (5.94 g.)	<i>i</i> -C ₄ H ₉ (H ₂ C=CHCH ₂) ₂ COH (72%)	292
<i>i</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₄ H ₉ (<i>n</i> -C ₃ H ₇) ₂ COH ("good yield")	149
<i>i</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgBr	<i>i</i> -C ₄ H ₉ (<i>n</i> -C ₄ H ₉) ₂ COH (60.5%)	340,327
<i>i</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	<i>s</i> -C ₄ H ₉ MgBr	(<i>i</i> -C ₄ H ₉) ₂ CO; <i>i</i> -C ₄ H ₉ CO- <i>s</i> -C ₄ H ₉	327
<i>i</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	<i>t</i> -C ₄ H ₉ MgCl	(<i>i</i> -C ₄ H ₉) ₂ CO; <i>i</i> -C ₄ H ₉ CO- <i>t</i> -C ₄ H ₉	327
<i>i</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	<i>t</i> -C ₄ H ₉ MgCl	<i>i</i> -C ₄ H ₉ CO- <i>t</i> -C ₄ H ₉	335
<i>i</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₄ H ₉ (<i>i</i> -C ₅ H ₁₁) ₂ COH	149
<i>i</i> -C ₄ H ₉ CO ₂ C ₂ H ₅ (60 g.)	C ₆ H ₅ MgBr (157 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ C=CH- <i>i</i> -C ₃ H ₇ (75 g.); (C ₆ H ₅ —) ₂	224
<i>i</i> -C ₄ H ₉ CO ₂ C ₂ H ₅ (24 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (0.189 mole)	<i>i</i> -C ₄ H ₉ COCH(<i>i</i> -C ₃ H ₇)CO ₂ C ₂ H ₅ (10 g., 51%); (CH ₃) ₃ C ₆ H ₃	396
<i>i</i> -C ₄ H ₉ CO ₂ - <i>t</i> -C ₄ H ₉ (29.2 g., 0.185 mole)	<i>i</i> -C ₃ H ₇ MgBr (0.0925 mole)	<i>i</i> -C ₄ H ₉ COCH(<i>i</i> -C ₃ H ₇)CO ₂ - <i>t</i> -C ₄ H ₉ (5.9 g., 29%); recovered ester (4.5 g., 15%); "gas"	384

* L-2-Carbethoxy-4-hydroxyproline hydrochloride.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₉O₂-R (cont.)			
<i>t</i> -C ₄ H ₉ CO ₂ CH ₃ (1.87 mole)	C ₂ H ₅ MgBr (4.5 moles)	C ₂ H ₅ (<i>t</i> -C ₄ H ₉)CHOH (8.6%); <i>t</i> -C ₄ H ₉ (C ₂ H ₅) ₂ COH (76.5%)	454
<i>t</i> -C ₄ H ₉ CO ₂ CH ₃	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (48%); <i>t</i> -C ₄ H ₉ (<i>n</i> -C ₃ H ₇) ₂ COH (40%)	454
<i>t</i> -C ₄ H ₉ CO ₂ CH ₃ (1.5 mole)	<i>i</i> -C ₃ H ₇ MgBr (4.5 moles)	<i>i</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (44.8%); recovered ester (34.2%)	454
<i>t</i> -C ₄ H ₉ CO ₂ CH ₃	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉)CHOH (40%)	454
<i>t</i> -C ₄ H ₉ CO ₂ CH ₃ (0.5 mole)	<i>i</i> -C ₄ H ₉ MgBr (1.7 mole)	<i>i</i> -C ₄ H ₉ CO- <i>t</i> -C ₄ H ₉ (29.4%); <i>i</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉)CHOH (25.7%); recovered ester (27.2%)	454
<i>t</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	C ₂ H ₅ MgI	C ₂ H ₅ (<i>t</i> -C ₄ H ₉)CHOH (13%); C ₂ H ₄ and C ₂ H ₆ in ratio of 1.7 : 1.0	238
<i>t</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgCl (2.5 equiv.)	<i>n</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (48%); <i>t</i> -C ₄ H ₉ (<i>n</i> -C ₃ H ₇) ₂ COH (40%); gas comprising C ₃ H ₆ (84%) and C ₃ H ₈ (6%)	238
<i>t</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH and <i>t</i> -C ₄ H ₉ (<i>n</i> -C ₃ H ₇) ₂ COH in ratio of 2.1 : 1.0	238
<i>t</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgI	<i>n</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH and <i>t</i> -C ₄ H ₉ (<i>n</i> -C ₃ H ₇) ₂ COH in ratio of 10 : 1	238
<i>t</i> -C ₄ H ₉ CO ₂ C ₂ H ₅ (1 mole)	<i>n</i> -C ₄ H ₉ MgBr (4 moles C ₄ H ₉ Br)	<i>n</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉)CHOH (40%); <i>t</i> -C ₄ H ₉ (<i>n</i> -C ₄ H ₉) ₂ COH (50%); <i>n</i> -C ₄ H ₉ OH	458, 451
<i>t</i> -C ₄ H ₉ CO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgI	<i>n</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉)CHOH	238
<i>t</i> -C ₄ H ₉ CO ₂ C ₂ H ₅ (12 g., 0.1 mole)	<i>t</i> -C ₄ H ₉ MgCl (0.6 mole)	Recovered ester (9 g.). [No (<i>t</i> -C ₄ H ₉) ₂ CO; no <i>t</i> -C ₄ H ₉ CH ₂ OH]	87
<i>t</i> -C ₄ H ₉ CO ₂ C ₂ H ₅ (26.8 g.)	<i>t</i> -C ₄ H ₉ C≡CMgBr (38.0 g. <i>t</i> -C ₄ H ₉ C≡CH)	<i>t</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉ C≡C) ₂ COH (78-82%)	126
<i>t</i> -C ₄ H ₉ CO ₂ CH ₂ CH=CH ₂ (34.6 g.)	C ₆ H ₅ MgBr (76.7 C ₆ H ₅ Br)	<i>t</i> -C ₄ H ₉ (C ₆ H ₅) ₂ COH (35.0 g.); recovered ester (7-10 g.)	4

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₉O₃-R			
HO(CH ₃)(C ₂ H ₅)CCO ₂ CH ₃ (132 g.)	CH ₃ MgI (568 g. CH ₃ I)	HO(CH ₃)(C ₂ H ₅)CC(CH ₃) ₂ OH (56%)	280
HO(CH ₃)(C ₂ H ₅)CCO ₂ CH ₃ (33 g.)	C ₆ H ₅ MgBr (157 g. C ₆ H ₅ Br)	HO(CH ₃)(C ₂ H ₅)CC(C ₆ H ₅) ₂ OH (45 g.)	281
(+)-CH ₃ (C ₂ H ₅ O)CHCO ₂ C ₂ H ₅	CH ₃ MgCl	(-)-CH ₃ (C ₂ H ₅ O)CHC(CH ₃) ₂ OH (85%)	407
HOCH ₂ (CH ₃) ₂ CCO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	HOCH ₂ (CH ₃) ₂ CC(C ₂ H ₅) ₂ OH; HOCH ₂ (CH ₃) ₂ CCH(C ₂ H ₅)OH	240
C₅H₁₀O₃ClN₂-R			
HCl·H ₂ NCH ₂ CONHCH(CH ₃)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	H ₂ NCH ₂ CONHCH(CH ₃)C(C ₆ H ₅) ₂ OH	45
HCl·H ₂ NCH ₂ COHNCH(CH ₃)CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	H ₂ NCH ₂ CONHCH(CH ₃)C(CH ₂ C ₆ H ₅) ₂ OH	45
C₆H₂O₅-R₂			
2,5-Dicarbethoxyfuran	C ₆ H ₅ MgBr	2,5-Bis-(α-hydroxybenzhydryl)furan	147
2,5-Dicarbethoxyfuran	C ₆ H ₅ CH ₂ MgCl	2,5-Bis-(1,3-diphenyl-2-hydroxyisopropyl)furan	147
C₆H₄O₂N-R			
Methyl nicotinate (137 g., 1.0 mole)	CH ₃ MgI (540 g., 3.25 moles CH ₃ I)	2-(3-Pyridyl)-2-propanol (78 g., 57%)	15,132
Ethyl picolinate	CH ₃ MgI	2-(2-Pyridyl)-2-propanol (86-90%)	392
Ethyl picolinate (12 g.)	C ₂ H ₅ MgBr (45 g. C ₂ H ₅ Br)	3-(2-Pyridyl)-3-pentanol (ca. 10 g.)	392
C₆H₆O₄-R₂			
C ₂ H ₅ CH=C(CO ₂ C ₂ H ₅) ₂ (0.16 mole)	1-C ₁₀ H ₇ CH ₂ MgCl (0.21 mole C ₁₁ H ₉ Cl)	C ₂ H ₅ (1-C ₁₀ H ₇ CH ₂)CHCH(CO ₂ C ₂ H ₅) ₂ (55%)	360
C ₂ H ₅ CH=C(CO ₂ C ₂ H ₅) ₂ (0.16 mole)	1-C ₁₀ H ₇ CH ₂ MgCl (0.21 mole C ₁₁ H ₉ Cl) + CdCl ₂ (0.20 mole)	C ₂ H ₅ (1-C ₁₀ H ₇ CH ₂)CHCH(CO ₂ C ₂ H ₅) ₂ (65%)	360
(CH ₃) ₂ C=C(CO ₂ C ₂ H ₅) ₂ (50 g.)	CH ₃ MgI (40 g. CH ₃ I)	<i>t</i> -C ₄ H ₉ CH(CO ₂ C ₂ H ₅) ₂ (20 g.)	464

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₆O₄-R₂ (<i>cont.</i>)			
(CH ₃) ₂ C=C(CO ₂ C ₂ H ₅) ₂ (30 g.)	<i>n</i> -C ₄ H ₉ MgBr (23 g. C ₄ H ₉ Br)	<i>n</i> -C ₄ H ₉ (CH ₃) ₂ CCH(CO ₂ C ₂ H ₅) ₂ (11.5 g.)	464
C₆H₆O₂N-R			
Ethyl 1-pyrrylacetate (23 g.)	CH ₃ MgI (56.4 g. CH ₃ I)	2-(1-Pyrrylmethyl)-2-propanol (18 g.)	50
Ethyl 1-pyrrylacetate (45 g.)	C ₂ H ₅ MgBr (1 mole)	3-(1-Pyrrylmethyl)-3-pentanol (38 g.)	50
C₆H₆O₅-R₂			
C ₂ H ₅ OCH=C(CO ₂ C ₂ H ₅) ₂	C ₂ H ₅ MgBr	(C ₂ H ₅) ₂ CHCH(CO ₂ C ₂ H ₅) ₂	356
C ₂ H ₅ OCH=C(CO ₂ C ₂ H ₅) ₂	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH(CO ₂ C ₂ H ₅) ₂	356
C₆H₆O₄-R₂			
(—CH ₂ CH ₂ CO ₂ CH ₃) ₂	C ₆ H ₅ MgBr	[—CH ₂ CH ₂ C(C ₆ H ₅) ₂ OH] ₂ (yielding 80–90% alkene)	377
(—CH ₂ CH ₂ CO ₂ C ₂ H ₅) ₂	CH ₃ MgBr	[—CH ₂ CH ₂ C(CH ₃) ₂ OH] ₂	284
(—CH ₂ CH ₂ CO ₂ C ₂ H ₅) ₂ (20.2 g.)	CH ₃ MgI (56.6 g. CH ₃ I)	[—CH ₂ CH ₂ C(CH ₃) ₂ OH] ₂ (16.0 g., 92%)	61,203,337
(—CH ₂ CH ₂ CO ₂ C ₂ H ₅) ₂ (20.2 g.)	C ₂ H ₅ MgI (62.4 g. C ₂ H ₅ I)	[—CH ₂ CH ₂ C(C ₂ H ₅) ₂ OH] ₂ (70%)	61
(—CH ₂ CH ₂ CO ₂ C ₂ H ₅) ₂ (20.2 g.)	<i>n</i> -C ₃ H ₇ MgI (68.0 g. C ₃ H ₇ I)	[—CH ₂ CH ₂ C(<i>n</i> -C ₃ H ₇) ₂ OH] ₂ (<i>ca.</i> 1.0 g.); unidentified viscous liquid	61
(—CH ₂ CH ₂ CO ₂ C ₂ H ₅) ₂ (40 g.)	<i>n</i> -C ₄ H ₉ MgBr (115 g. C ₄ H ₉ Br)	[—CH ₂ CH ₂ C(<i>n</i> -C ₄ H ₉) ₂ OH] ₂ (62%)	337
(—CH ₂ CH ₂ CO ₂ C ₂ H ₅) ₂ (40 g.)	<i>i</i> -C ₄ H ₉ MgBr (160 g. C ₄ H ₉ Br)	[—CH ₂ CH ₂ C(<i>i</i> -C ₄ H ₉) ₂ OH] ₂ (38 g.); <i>i</i> -C ₄ H ₈ ; <i>i</i> -C ₄ H ₁₀	337
(—CH ₂ CH ₂ CO ₂ C ₂ H ₅) ₂ (20.2 g.)	C ₆ H ₅ MgBr (65.0 g. C ₆ H ₅ Br)	[—CH ₂ CH ₂ C(C ₆ H ₅) ₂ OH] ₂	61
(—CH ₂ CH ₂ CO ₂ C ₂ H ₅) ₂ (20.2 g.)	(CH ₂) ₅ CHMgCl (47.4 g. C ₆ H ₁₁ Cl)	{—CH ₂ CH ₂ C[CH(CH ₂) ₅]OH} ₂ (1.5 g.); (CH ₂) ₅ CHOC ₂ H ₅ ; C ₆ H ₁₀	61
(—CH ₂ CH ₂ CO ₂ C ₂ H ₅) ₂ (20.2 g.)	C ₆ H ₅ CH ₂ MgCl (50.6 g. C ₇ H ₇ Cl)	[—CH ₂ CH ₂ C(CH ₂ C ₆ H ₅) ₂ OH] ₂ (19.0 g., 40%); (—CH ₂ C ₆ H ₅) ₂ (7.0 g.)	61

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₈O₆-R₂			
D-[—CH(OCH ₃)CO ₂ CH ₃] ₂ (20 g.)	CH ₃ MgI (62 g. CH ₃ I)	[—CH(OCH ₃)C(CH ₃) ₂ OH] ₂ (9 g.)	347
D-[—CH(OCH ₃)CO ₂ CH ₃] ₂	C ₆ H ₅ MgBr (6 equiv.)	2,2,5,5-Tetraphenyl-3,4-dimethoxytetrahydrofuran	347
C₆H₉O₂-R			
(CH ₂) ₄ CHCO ₂ C ₂ H ₅ (45.0 g.)	CH ₃ MgI (15.3 g. Mg)	(CH ₂) ₄ CHC(CH ₃) ₂ OH (66.6%)	299
(CH ₂) ₄ CHCO ₂ C ₂ H ₅ (37 g.)	(CH ₂) ₄ CHMgCl (104 g. C ₅ H ₉ Cl)	[(CH ₂) ₄ CH] ₃ COH	306
C₆H₉O₃-R			
(CH ₂) ₄ C(OH)CO ₂ CH ₃ (72 g.)	CH ₃ MgI (213 g. CH ₃ I)	(CH ₂) ₄ C(OH)C(CH ₃) ₂ OH (70 g., <i>ca.</i> 50%)	282
(CH ₂) ₄ C(OH)CO ₂ CH ₃	C ₂ H ₅ MgBr (4 equiv.)	(CH ₂) ₄ C(OH)C(C ₂ H ₅) ₂ OH (60%)	280
(CH ₂) ₄ C(OH)CO ₂ CH ₃	C ₂ H ₅ MgBr (5 equiv.)	(CH ₂) ₄ C(OH)C(C ₂ H ₅) ₂ OH (72%)	280
(CH ₂) ₄ C(OH)CO ₂ CH ₃ (158 g.)	C ₂ H ₅ MgBr (436 g. C ₂ H ₅)	(CH ₂) ₄ C(OH)C(C ₂ H ₅) ₂ OH; (CH ₂) ₄ C(OH)CH(C ₂ H ₅)OH (144 g. glycol mixture)	281
(CH ₂) ₄ C(OH)CO ₂ CH ₃ (144 g.)	<i>n</i> -C ₃ H ₇ MgBr (492 g. C ₃ H ₇ Br)	(CH ₂) ₄ C(OH)C(<i>n</i> -C ₃ H ₇) ₂ OH; (CH ₂) ₄ C(OH)CH(<i>n</i> -C ₃ H ₇)OH (160 g. glycol mixture, of which <i>ca.</i> 60% is the normal product)	281
CH ₃ CO(C ₂ H ₅)CHCO ₂ C ₂ H ₅ (53 g.)	CH ₃ MgI (3 equiv.)	HO(CH ₃) ₂ CCH(C ₂ H ₅)CO ₂ C ₂ H ₅ ; recovered ester	137
CH ₃ CO(C ₂ H ₅)CHCO ₂ C ₂ H ₅	CH ₃ MgI (3 equiv.)	HO(CH ₃) ₂ CCH(C ₂ H ₅)CO ₂ C ₂ H ₅ ; [HO(CH ₃) ₂ C] ₂ CHC ₂ H ₅ ("very poor yield"); recovered ester (<i>ca.</i> 30 g.)	139,137
CH ₃ CO(CH ₃) ₂ CCO ₂ C ₂ H ₅	CH ₃ MgI	[HO(CH ₃) ₂ C] ₂ C(CH ₃) ₂	387
C₆H₉O₄N-R₂			
H ₅ C ₂ O ₂ C(CH ₂) ₃ CH(NH ₂)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	α'-(α-Piperidonyl)diphenylmethanol	188,189
C₆H₁₀O₃N-R			
(C ₂ H ₅) ₂ NCOCOC ₂ H ₅ (20 g.)	C ₂ H ₅ MgBr (1.5 equiv.)	(C ₂ H ₅) ₂ NCOCOC ₂ H ₅ (70%); (C ₂ H ₅) ₂ NCOC(C ₂ H ₅) ₂ OH; recovered ester	29
(C ₂ H ₅) ₂ NCOCOC ₂ H ₅ (20 g.)	C ₂ H ₅ MgBr (2 equiv.)	(C ₂ H ₅) ₂ NCOCOC ₂ H ₅ ; unchanged ester	29

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₀O₃N-R (cont.)			
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅ (20 g.)	C ₂ H ₅ MgBr (2.25 equiv.)	(C ₂ H ₅) ₂ NCOC(C ₂ H ₅) ₂ OH (70%); (C ₂ H ₅) ₂ NCOCOC ₂ H ₅ (20%); recovered ester	28,29
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅ (20 g.)	C ₂ H ₅ MgBr (3 equiv.)	(C ₂ H ₅) ₂ NCOC(C ₂ H ₅) ₂ OH (80%); (C ₂ H ₅) ₂ NCOCOC ₂ H ₅ (2-3%); (C ₂ H ₅ CO—) ₂	29
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅ (20 g.)	C ₂ H ₅ MgBr (5 equiv.)	(C ₂ H ₅) ₂ NCOC(C ₂ H ₅) ₂ OH; (C ₂ H ₅ CO—) ₂	29
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅ (10 g.)	C ₂ H ₅ MgI (27 g. C ₂ H ₅ I)	(C ₂ H ₅) ₂ NCOC(C ₂ H ₅) ₂ OH (5.5 g.)	268
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgBr	(C ₂ H ₅) ₂ NCOCO- <i>n</i> -C ₄ H ₉ (90%); (C ₂ H ₅) ₂ NCOC(<i>n</i> -C ₄ H ₉) ₂ OH (trace); diketone (trace)	29
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅	C ₆ H ₅ MgBr (1.6 equiv.)	(C ₂ H ₅) ₂ NCOC(C ₆ H ₅) ₂ OH (63%); (C ₂ H ₅) ₂ NCOCOC ₆ H ₅ (15%)	29
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅	C ₆ H ₅ MgBr (2 equiv.)	(C ₂ H ₅) ₂ NCOCOC ₆ H ₅ (63%)	29
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅ (22 g.)	C ₆ H ₅ MgBr (80 g. C ₆ H ₅ Br)	(C ₂ H ₅) ₂ NCOC(C ₆ H ₅) ₂ OH (23 g.); (C ₆ H ₅ —) ₂	268
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl	(C ₂ H ₅) ₂ NCOCOCH ₂ C ₆ H ₅ (70%); (C ₂ H ₅) ₂ NCOC(CH ₂ C ₆ H ₅) ₂ OH (15%)	29
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅ (15 g.)	C ₆ H ₅ CH ₂ MgCl (44 g. C ₇ H ₇ Cl)	(C ₂ H ₅) ₂ NCOC(CH ₂ C ₆ H ₅) ₂ OH (8 g.)	268
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅ (12 g.)	2-CH ₃ C ₆ H ₄ MgBr (48 g. C ₇ H ₇ Br)	(C ₂ H ₅) ₂ NCOC(C ₆ H ₄ -2-CH ₃) ₂ OH (11 g.)	268
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅ (8.8 g.)	4-CH ₃ C ₆ H ₄ MgBr (35 g. C ₇ H ₇ Br)	(C ₂ H ₅) ₂ NCOC(C ₆ H ₄ -4-CH ₃) ₂ OH (6 g.); (4-CH ₃ C ₆ H ₄ —) ₂	268
(C ₂ H ₅) ₂ NCOCO ₂ C ₂ H ₅ (20 g.)	1-C ₁₀ H ₇ MgBr (96 g. C ₁₀ H ₇ Br)	(C ₂ H ₅) ₂ NCOC(1-C ₁₀ H ₇) ₂ OH (30 g.); (1-C ₁₀ H ₇ —) ₂	268
C₆H₁₁O₂-R			
<i>n</i> -C ₅ H ₁₁ CO ₂ C ₂ H ₅	CH ₃ MgCl	<i>n</i> -C ₅ H ₁₁ (CH ₃) ₂ COH (61%)	461,80
<i>n</i> -C ₅ H ₁₁ CO ₂ C ₂ H ₅	CH ₃ MgX*	<i>n</i> -C ₅ H ₁₁ (CH ₃) ₂ COH	298

* X = Br, I.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₁O₂·R (cont.)			
<i>n</i> -C ₅ H ₁₁ CO ₂ C ₂ H ₅	CH ₃ MgX (2 equiv.)	<i>n</i> -C ₅ H ₁₁ (CH ₃) ₂ COH (80–85%); corresponding olefin (<i>ca.</i> 1%)	259
<i>n</i> -C ₅ H ₁₁ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	<i>n</i> -C ₅ H ₁₁ (C ₂ H ₅) ₂ COH (73%)	461,80
<i>n</i> -C ₅ H ₁₁ CO ₂ C ₂ H ₅	C ₂ H ₅ MgX (2 equiv.)	<i>n</i> -C ₅ H ₁₁ (C ₂ H ₅) ₂ COH (80–85%); corresponding olefin (<i>ca.</i> 1%)	259
<i>n</i> -C ₅ H ₁₁ CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₅ H ₁₁ (<i>n</i> -C ₃ H ₇) ₂ COH (44%)	461,80
<i>n</i> -C ₅ H ₁₁ CO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₅ H ₁₁ (<i>n</i> -C ₄ H ₉) ₂ COH (76%)	461
<i>n</i> -C ₅ H ₁₁ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	<i>n</i> -C ₅ H ₁₁ (C ₆ H ₅) ₂ COH	260,224
<i>n</i> -C ₅ H ₁₁ CO ₂ C ₂ H ₅ (154 g.)	<i>n</i> -C ₁₀ H ₂₁ MgBr (660 g. C ₁₀ H ₂₁ Br)	<i>n</i> -C ₅ H ₁₁ (<i>n</i> -C ₁₀ H ₂₁) ₂ COH (345 g.); C ₁₀ H ₂₂ (80 g.); <i>n</i> -C ₅ H ₁₁ CO- <i>n</i> -C ₁₀ H ₂₁ (40 g.)	483
<i>i</i> -C ₅ H ₁₁ CO ₂ C ₂ H ₅ (57.6 g.)	C ₆ H ₅ MgBr (157 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ C=CH- <i>i</i> -C ₄ H ₉ (50 g.)	224
<i>t</i> -C ₄ H ₉ CH ₂ CO ₂ CH ₃ (1 mole)	C ₂ H ₅ MgBr (4 moles)	<i>t</i> -C ₄ H ₉ CH ₂ (C ₂ H ₅) ₂ COH (68.5%); C ₂ H ₅ COCH ₂ - <i>t</i> -C ₄ H ₉ (5.0%)	454
<i>t</i> -C ₄ H ₉ CH ₂ CO ₂ CH ₃ (1 mole)	<i>n</i> -C ₃ H ₇ MgBr (4 moles)	<i>t</i> -C ₄ H ₉ CH ₂ (<i>n</i> -C ₃ H ₇) ₂ COH (61.8%); <i>n</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (20.4%); <i>n</i> -C ₃ H ₇ COCH ₂ - <i>t</i> -C ₄ H ₉ (7.0%)	454
<i>t</i> -C ₄ H ₉ CH ₂ CO ₂ CH ₃ (1 mole)	<i>i</i> -C ₃ H ₇ MgBr (4 moles)	<i>i</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (16.1%); <i>i</i> -C ₃ H ₇ COCH ₂ - <i>t</i> -C ₄ H ₉ (55.3%)	454
<i>t</i> -C ₄ H ₉ CH ₂ CO ₂ CH ₃ (0.9 mole)	<i>n</i> -C ₄ H ₉ MgBr (3.6 moles)	<i>t</i> -C ₄ H ₉ CH ₂ (<i>n</i> -C ₄ H ₉) ₂ COH (71.4%); <i>n</i> -C ₄ H ₉ COCH ₂ - <i>t</i> -C ₄ H ₉ (trace)	454
<i>t</i> -C ₄ H ₉ CH ₂ CO ₂ CH ₃ (0.5 mole)	<i>i</i> -C ₄ H ₉ MgBr (1.7 atom Mg)	<i>t</i> -C ₄ H ₉ CH ₂ (<i>i</i> -C ₄ H ₉) ₂ COH (34.2%); <i>i</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (9.2%); <i>i</i> -C ₄ H ₉ COCH ₂ - <i>t</i> -C ₄ H ₉ (32.0%)	454
<i>t</i> -C ₄ H ₉ CH ₂ CO ₂ C ₂ H ₅ (27.0 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (0.194 mole)	<i>t</i> -C ₄ H ₉ CH ₂ CO(<i>t</i> -C ₄ H ₉)CHCO ₂ C ₂ H ₅ (7.3 g., 32%)	396
(-)-CH ₃ (<i>n</i> -C ₃ H ₇)CHCO ₂ CH ₃ (5.0 g.)	C ₆ H ₅ MgBr (18.5 g. C ₆ H ₅ Br)	DL-CH ₃ (<i>n</i> -C ₃ H ₇)CHC(C ₆ H ₅) ₂ OH (3.5 g.)	38
DL-CH ₃ (<i>n</i> -C ₃ H ₇)CHCO ₂ CH ₃ (7.0 g.)	C ₆ H ₅ MgBr (26.0 g. C ₆ H ₅ Br)	DL-CH ₃ (<i>n</i> -C ₃ H ₇)CHC(C ₆ H ₅) ₂ OH (7.0 g.)	38

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₁O₂-R (cont.)			
(-)-CH ₃ (<i>n</i> -C ₃ H ₇)CHCO ₂ C ₂ H ₅	CH ₃ MgI	After dehydr'n and hydrogen'n, (-)-CH ₃ (<i>n</i> -C ₃ H ₇)(<i>i</i> -C ₃ H ₇)CH	242
(-)-CH ₃ (<i>n</i> -C ₃ H ₇)CHCO ₂ C ₂ H ₅ (4.0 g.)	C ₂ H ₅ MgBr (11.0 g. C ₂ H ₅ Br)	(-)-CH ₃ (<i>n</i> -C ₃ H ₇)CHC(C ₂ H ₅) ₂ OH (2.9 g.)	37
(C ₂ H ₅) ₂ CHCO ₂ C ₂ H ₅	CH ₃ MgI (3 equiv.)	C ₈ H ₁₆ (small quantity)	137
(C ₂ H ₅) ₂ CHCO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	(C ₂ H ₅) ₂ C=C(C ₆ H ₅) ₂	109
(C ₂ H ₅) ₂ CHCO ₂ C ₂ H ₅	4-CH ₃ OC ₆ H ₄ MgBr (2 equiv.)	(C ₂ H ₅) ₂ C=C(C ₆ H ₄ -4-OCH ₃) ₂	109
(C ₂ H ₅) ₂ CHCO ₂ C ₂ H ₅	<i>n</i> -C ₁₀ H ₂₁ MgBr	(C ₂ H ₅) ₂ CHC(<i>n</i> -C ₁₀ H ₂₁) ₂ OH (yielding 36% paraffin)	483
(C ₂ H ₅) ₂ CHCO ₂ CH ₂ CH=CH ₂ (25.3 g.)	C ₆ H ₅ MgBr (45.0 ml. C ₆ H ₅ Br)	(C ₂ H ₅) ₂ CHCO ₂ H (4.5 g.); C ₆ H ₅ CH ₂ CH=CH ₂ (9.0 g.); (C ₂ H ₅) ₂ CHC(C ₆ H ₅) ₂ OH (10.3 g.)	6
C ₂ H ₅ (CH ₃) ₂ CCO ₂ C ₂ H ₅	CH ₃ MgBr	Addition (100%); enolization (0%)*	457
C₆H₁₁O₃-R			
L-C ₂ H ₅ (C ₂ H ₅ O)CHCO ₂ C ₂ H ₅	CH ₃ MgI	L-C ₂ H ₅ (C ₂ H ₅ O)CHC(CH ₃) ₂ OH	243
C₆H₁₁O₄-R			
(C ₂ H ₅ O) ₂ CHCO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	(C ₂ H ₅ O) ₂ CHC(C ₆ H ₅) ₂ OH (70%)	369
C₆H₁₂O₂N-R			
(C ₂ H ₅) ₂ NCH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgI	(C ₂ H ₅) ₂ NCH ₂ C(C ₂ H ₅) ₂ OH	318
(C ₂ H ₅) ₂ NCH ₂ CO ₂ C ₂ H ₅ (12 g.)	C ₆ H ₅ MgBr (25.7 g. C ₆ H ₅ Br)	(C ₂ H ₅) ₂ NCH ₂ C(C ₆ H ₅) ₂ OH (10 g., crude)	318
<i>i</i> -C ₄ H ₉ CH(NH ₂)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	<i>i</i> -C ₄ H ₉ CH(NH ₂)C(C ₂ H ₅) ₂ OH	191
DL- <i>i</i> -C ₄ H ₉ CH(NH ₂)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	DL- <i>i</i> -C ₄ H ₉ CH(NH ₂)C(C ₆ H ₅) ₂ OH	191
DL- <i>i</i> -C ₄ H ₉ CH(NH ₂)CO ₂ C ₂ H ₅	4-CH ₃ C ₆ H ₄ MgBr	DL- <i>i</i> -C ₄ H ₉ CH(NH ₂)C(C ₆ H ₄ -4-CH ₃) ₂ OH	191
L(+)- <i>i</i> -C ₄ H ₉ CH(NH ₂)CO ₂ C ₂ H ₅	CH ₃ MgBr	(-)- <i>i</i> -C ₄ H ₉ CH(OH)C(CH ₃) ₂ OH	192

* "Grignard machine" study.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₂O₂N-R (cont.)			
L(+)- <i>i</i> -C ₄ H ₉ CH(NH ₂)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	(-)- <i>i</i> -C ₄ H ₉ CH(OH)C(C ₂ H ₅) ₂ OH	192
L(+)- <i>i</i> -C ₄ H ₉ CH(NH ₂)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	L(-)- <i>i</i> -C ₄ H ₉ CH(NH ₂)C(C ₆ H ₅) ₂ OH (56%)	191
L(+)- <i>i</i> -C ₄ H ₉ CH(NH ₂)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	(-)- <i>i</i> -C ₄ H ₉ CH(OH)C(C ₆ H ₅) ₂ OH (72%)	192
L(+)- <i>i</i> -C ₄ H ₉ CH(NH ₂)CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl	L(+)- <i>i</i> -C ₄ H ₉ CH(NH ₂)C(CH ₂ C ₆ H ₅) ₂ OH	191
L(+)- <i>i</i> -C ₄ H ₉ CH(NH ₂)CO ₂ C ₂ H ₅	4-CH ₃ C ₆ H ₄ MgBr	L(-)- <i>i</i> -C ₄ H ₉ CH(NH ₂)C(C ₆ H ₄ -4-CH ₃) ₂ OH	191
C₆H₁₃O₂ClN-R			
<i>i</i> -C ₄ H ₉ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	<i>i</i> -C ₄ H ₉ CH(NH ₂)C(C ₆ H ₅) ₂ OH (62%)	43
<i>i</i> -C ₄ H ₉ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	<i>i</i> -C ₄ H ₉ CH(NH ₂)C(CH ₂ C ₆ H ₅) ₂ OH (61%)	43
C₇H₂O₂Br₃-R			
2,4,6-Br ₃ C ₆ H ₂ CO ₂ CH ₃ (4 g., 0.011 mole)	C ₆ H ₅ MgBr (13 g., 0.082 mole C ₆ H ₅ Br)	Recovered ester (ca. quant.)*	291
2,4,6-Br ₃ C ₆ H ₂ CO ₂ CH ₃ (4 g., 0.011 mole)	C ₆ H ₅ MgBr (13 g., 0.082 mole C ₆ H ₅ Br)	2,4,6-Br ₃ C ₆ H ₂ (C ₆ H ₅) ₂ COH (1.5 g., 28%)†	291
C₇H₃O₂Cl₂-R			
2,4-Cl ₂ C ₆ H ₃ CO ₂ C ₂ H ₅ (110 g., 0.5 mole)	CH ₃ MgI (9.1 moles)	2,4-Cl ₂ C ₆ H ₃ (CH ₃) ₂ COH (yielding 64 g., 68% olefin)	13
3,4-Cl ₂ C ₆ H ₃ CO ₂ C ₂ H ₅ (410 g.)	CH ₃ MgI (excess)	3,4-Cl ₂ C ₆ H ₃ (CH ₃) ₂ COH (yielding 248 g., 70% olefin)	13
C₇H₃O₃Br₂-R			
2-HO-3,5-Br ₂ C ₆ H ₂ CO ₂ CH ₃ (10 g.)	C ₆ H ₅ MgBr (21 g. C ₆ H ₅ Br)	2-HO-3,5-Br ₂ C ₆ H ₂ (C ₆ H ₅) ₂ COH (10 g.)	197
C₇H₄O₂Br-R			
2-BrC ₆ H ₄ CO ₂ CH ₃	4-ClC ₆ H ₄ MgI	2-BrC ₆ H ₄ (4-ClC ₆ H ₄) ₂ COH (isolated as chloride, 74%)	131

* Gradual addition of Et₂O-ester solution to Grignard reagent solution; five hours reflux.

† Gradual addition of Et₂O-ester solution to Grignard reagent solution; four hours at 80-85°.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₄O₂Br-R (cont.)			
2-BrC ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr	2-BrC ₆ H ₄ (C ₆ H ₅) ₂ COH (54%)	131
2-BrC ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	2-BrC ₆ H ₄ (C ₆ H ₅) ₂ COH	255
3-BrC ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	3-BrC ₆ H ₄ (C ₆ H ₅) ₂ COH	255
4-BrC ₆ H ₄ CO ₂ CH ₃	4-ClC ₆ H ₄ MgI	4-BrC ₆ H ₄ (4-ClC ₆ H ₄) ₂ COH (65%)	131
4-BrC ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	4-BrC ₆ H ₄ (C ₆ H ₅) ₂ COH	255
C₇H₄O₂Cl-R			
2-ClC ₆ H ₄ CO ₂ CH ₃ (170 g.)	CH ₃ MgI (355 g. CH ₃ I)	2-ClC ₆ H ₄ (CH ₃) ₂ COH (140 g., 82.5%)	65
2-ClC ₆ H ₄ CO ₂ CH ₃ (12.5 g.)	C ₆ H ₅ MgBr (30 g. C ₆ H ₅ Br)	2-ClC ₆ H ₄ (C ₆ H ₅) ₂ COH (11.8 g.)	131,222
2-ClC ₆ H ₄ CO ₂ C ₂ H ₅	CH ₃ MgI (excess)	2-ClC ₆ H ₄ (CH ₃) ₂ COH (yielding 60% olefin)	13
2-ClC ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	2-ClC ₆ H ₄ (C ₆ H ₅) ₂ COH	255
3-ClC ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	3-ClC ₆ H ₄ (C ₆ H ₅) ₂ COH	255
4-ClC ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	4-ClC ₆ H ₄ (C ₆ H ₅) ₂ COH	255
C₇H₄O₂F-R			
2-FC ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	2-FC ₆ H ₄ (C ₆ H ₅) ₂ COH	255
4-FC ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	4-FC ₆ H ₄ (C ₆ H ₅) ₂ COH	255
C₇H₄O₂I-R			
4-IC ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	4-IC ₆ H ₄ (C ₆ H ₅) ₂ COH	255
C₇H₅O₂-R			
C ₆ H ₅ CO ₂ CH ₃	CH ₃ MgI	C ₆ H ₅ (CH ₃) ₂ COH (78%)	493
C ₆ H ₅ CO ₂ CH ₃	C ₂ H ₅ I + Mg*	C ₆ H ₅ (C ₂ H ₅) ₂ COH	488
C ₆ H ₅ CO ₂ CH ₃	<i>i</i> -C ₄ H ₉ MgBr	<i>i</i> -C ₄ H ₉ (C ₆ H ₅)CHOH (ca. 35%)	378
C ₆ H ₅ CO ₂ CH ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ COH (87%); (C ₆ H ₅ —) ₂	434,424

* Without solvent (other than the reactants).

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₅O₂-R (cont.)			
C ₆ H ₅ CO ₂ CH ₃	C ₆ H ₅ MgBr	[(C ₆ H ₅) ₃ C] ₂ O; (C ₆ H ₅) ₃ COH	401
C ₆ H ₅ CO ₂ CH ₃ (14 g.)	C ₆ H ₅ MgBr (34 g. C ₆ H ₅ Br)	CH ₃ OC(C ₆ H ₅) ₃ * (9 g.); (C ₆ H ₅) ₃ COH (7 g.)	402
C ₆ H ₅ CO ₂ CH ₃ (14 g.)	C ₆ H ₅ MgBr (34 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ COH (13.3 g., 49.7%); [(C ₆ H ₅) ₂ COH—] ₂ (0.11 g.); C ₂ H ₅ OC(C ₆ H ₅) ₃ (1.62 g., 5.7%)	63
C ₆ H ₅ CO ₂ CH ₃ (20.9 g.)	C ₆ H ₅ MgBr (24.1 g. C ₆ H ₅ Br) + Mg + Hg	(C ₆ H ₅) ₃ COH (8.3 g., 41.5%); [(C ₆ H ₅) ₂ COH—] ₂ (2.15 g., 7.8%)	63
C ₆ H ₅ CO ₂ CH ₃ (20.9 g.)	C ₆ H ₅ MgBr (24.4 g. C ₆ H ₅ Br) + Mg	(C ₆ H ₅) ₃ COH (8.7 g., 43.5%); [(C ₆ H ₅) ₂ COH—] ₂ (0.6 g., 2.2%); (C ₆ H ₅) ₂ CO; (C ₆ H ₅ —) ₂ ; C ₂ H ₅ OC(C ₆ H ₅) ₃ ; recovered ester	63
C ₆ H ₅ CO ₂ CH ₃	4-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ (4-CH ₃ C ₆ H ₄) ₂ COH	206
C ₆ H ₅ CO ₂ CH ₃	2,4-(CH ₃ O) ₂ C ₆ H ₃ MgI	C ₆ H ₅ [2,4-(CH ₃ O) ₂ C ₆ H ₃] ₂ COH (ca. 60%)	248
C ₆ H ₅ CO ₂ CH ₃	<i>n</i> -C ₁₀ H ₂₁ MgBr	C ₆ H ₅ (<i>n</i> -C ₁₀ H ₂₁) ₂ COH (yielding 75% olefin)	453
C ₆ H ₅ CO ₂ C ₂ H ₅	CH ₃ MgBr	CH ₃ (C ₆ H ₅)C=CH ₂	182
C ₆ H ₅ CO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgCl	C ₆ H ₅ (<i>n</i> -C ₄ H ₉) ₂ COH (72%)	328
C ₆ H ₅ CO ₂ C ₂ H ₅	<i>i</i> -C ₄ H ₉ MgX†	<i>i</i> -C ₄ H ₉ (C ₆ H ₅)CHOH; C ₆ H ₅ CO ₂ CH(CH ₃)- <i>i</i> -C ₄ H ₉	328
C ₆ H ₅ CO ₂ C ₂ H ₅	<i>t</i> -C ₄ H ₉ MgCl	(C ₆ H ₅) ₂ CHOH (36%)	329
C ₆ H ₅ CO ₂ C ₂ H ₅	2-Pyridyl-MgBr	Phenylbis-(2-pyridyl)methanol	344
C ₆ H ₅ CO ₂ C ₂ H ₅ (30 g.)	C ₆ H ₅ MgBr (35 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ COH (42%); C ₂ H ₅ OC(C ₆ H ₅) ₃ (31%)	402
C ₆ H ₅ CO ₂ C ₂ H ₅ (75 g.)	C ₆ H ₅ MgBr (181 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ COH (116–121 g., 89–93%)	17
C ₆ H ₅ CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ (C ₆ H ₅ CH ₂) ₂ COH	205
C ₆ H ₅ CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ Cl + Mg	C ₆ H ₅ (C ₆ H ₅ CH ₂) ₂ COH (60%)	94
C ₆ H ₅ CO ₂ C ₂ H ₅ (120 g.)	2-CH ₃ C ₆ H ₄ MgBr (342 g. C ₇ H ₇ Br)	C ₆ H ₅ (2-CH ₃ C ₆ H ₄) ₂ COH (87 g.)	257

* Cf. Boyd and Hatt (63), who suggest that this product is actually the ethyl ether, formed during ethyl alcohol crystallization of the normal product.

† X = Cl, Br.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₅O₂-R (cont.)			
C ₆ H ₅ CO ₂ C ₂ H ₅ (68 g.)	3-CH ₃ C ₆ H ₄ MgBr (171 g. C ₇ H ₇ Br)	C ₆ H ₅ (3-CH ₃ C ₆ H ₄) ₂ COH (105 g.)	257
C ₆ H ₅ CO ₂ C ₂ H ₅ (52 g.)	4-CH ₃ C ₆ H ₄ MgBr (129 g. C ₇ H ₇ Br)	C ₆ H ₅ (4-CH ₃ C ₆ H ₄) ₂ COH (yielding 19 g. chloride)	257,222
C ₆ H ₅ CO ₂ C ₂ H ₅ C ₆ H ₅ CO ₂ C ₂ H ₅ (10 g.)	C ₆ H ₅ CH(CO ₂ Na)MgCl* 2-(CH ₃) ₂ NC ₆ H ₄ MgI (10 g. C ₈ H ₁₀ IN)	C ₆ H ₅ COCH ₂ C ₆ H ₅ (14.4%); C ₆ H ₅ CH ₂ OH C ₆ H ₅ [2-(CH ₃) ₂ NC ₆ H ₄] ₂ COH (10 g.)	405 20
C ₆ H ₅ CO ₂ C ₂ H ₅ (35 g.)	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ MgBr (100 g. C ₉ H ₁₁ Br)	C ₆ H ₅ (4- <i>i</i> -C ₃ H ₇ C ₆ H ₄) ₂ COH (yielding 21 g. chloride)	257
C ₆ H ₅ CO ₂ C ₂ H ₅ (37 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (50 g. C ₉ H ₁₁ Br)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC ₆ H ₅ (17.4 g.)	233
C ₆ H ₅ CO ₂ C ₂ H ₅ (35 g.)	4- <i>s</i> -C ₄ H ₉ C ₆ H ₄ MgBr (107 g. C ₁₀ H ₁₃ Br)	C ₆ H ₅ (4- <i>s</i> -C ₄ H ₉ C ₆ H ₄) ₂ COH (yielding 21 g. chloride)	257
C ₆ H ₅ CO ₂ C ₂ H ₅ (21.5 g.)	4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ MgBr (70 g. C ₁₀ H ₁₃ Br)	C ₆ H ₅ (4- <i>t</i> -C ₄ H ₉ C ₆ H ₄) ₂ COH (yielding 14 g. chloride)	257
C ₆ H ₅ CO ₂ C ₂ H ₅ (22.5 g.)	4- <i>t</i> -C ₅ H ₁₁ C ₆ H ₄ MgBr (76 g. C ₁₁ H ₁₅ Br)	C ₆ H ₅ (4- <i>t</i> -C ₅ H ₁₁ C ₆ H ₄) ₂ COH (yielding 9 g. chloride)	257
C ₆ H ₅ CO ₂ C ₂ H ₅	(CH ₃) ₅ C ₆ MgBr	(CH ₃) ₅ C ₆ C ₂ H ₅ [†] ; C ₂ H ₅ (C ₆ H ₅)CHOH†(CH ₃) ₅ C ₆ H; C ₆ H ₅ COC ₆ (CH ₃) ₅	85,84
C ₆ H ₅ CO ₂ C ₂ H ₅ (15 g.)	9-Phenanthryl-MgBr (25 g. C ₁₄ H ₉ Br)	Phenyldi-9-phenanthrylmethanol (20%); di-9-phenanthrylmethane (?)	39
C ₆ H ₅ CO ₂ CH ₂ CH=CH ₂ (16.2 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (25.0 g. C ₉ H ₁₁ Br)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC ₆ H ₅ (2.4 g., 11%); 2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂ CH=CH ₂ (5.7 g., 36%); C ₆ H ₅ CO ₂ H (5.1 g., 42%); recovered ester (26%)	8

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

† Attributable to the use of ethyl bromide as "entrainer" in the preparation of the Grignard reagent.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₅O₂-R (cont.)			
C ₆ H ₅ CO ₂ CH ₂ COCH ₃	C ₂ H ₅ MgBr (4 equiv.)	C ₆ H ₅ (C ₂ H ₅) ₂ COH; HOCH ₂ (CH ₃)(C ₂ H ₅)COH; C ₆ H ₅ CO ₂ H	207
C ₆ H ₅ CO ₂ - <i>t</i> -C ₄ H ₉ (0.3 mole)	C ₆ H ₅ MgBr (0.5 mole C ₆ H ₅ Br)	(C ₆ H ₅) ₃ COH (41%); C ₆ H ₅ CO ₂ H (10%)	117
C ₆ H ₅ CO ₂ C ₆ H ₅	(C ₆ H ₅) ₃ CmgbBr	C ₆ H ₅ COC(C ₆ H ₅) ₃ (46%)	16
C ₆ H ₅ CO ₂ CH ₂ C ₆ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ COH (60%); C ₆ H ₅ CH ₂ OC(C ₆ H ₅) ₃ (2.3%)*	401
C ₆ H ₅ CO ₂ CH ₂ C ₆ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ COH (15%); C ₆ H ₅ CH ₂ OC(C ₆ H ₅) ₃ (30%); C ₆ H ₅ CH ₂ Br†	401
C ₆ H ₅ CO ₂ CH ₂ C ₆ H ₅ (40 g.)	C ₆ H ₅ MgBr (60 g. C ₆ H ₅ Br)	C ₆ H ₅ OH; C ₆ H ₅ CO ₂ H; C ₆ H ₅ CH ₂ OH; C ₆ H ₅ CH=C(C ₆ H ₅) ₂ † (0.55 g.); (C ₆ H ₅) ₃ COH (35.6 g., 75%); unidentified oil (6.0 g.)§	398
C ₆ H ₅ CO ₂ CH ₂ C ₆ H ₅ (20 g.)	C ₆ H ₅ MgBr (16 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ COH (15%); C ₆ H ₅ CH ₂ OC(C ₆ H ₅) ₃ (30%)¶	398
C ₆ H ₅ CO ₂ CH ₂ C ₆ H ₅ (45 g.)	C ₆ H ₅ MgBr (65 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ COH (60%); C ₆ H ₅ CH ₂ OC(C ₆ H ₅) ₃ (2.3%); C ₆ H ₅ CH ₂ OH; recovered ester‡	402
C ₆ H ₅ CO ₂ CH ₂ C ₆ H ₅ (40 g.)	C ₆ H ₅ MgBr (60 g. C ₆ H ₅ Br)	C ₆ H ₅ CO ₂ H (0.25 g.); (C ₆ H ₅) ₃ COH (29.1 g.); C ₆ H ₅ Br (5.9 g.); C ₆ H ₅ CH ₂ OH (12.8 g.); (C ₆ H ₅ -) ₂ (0.57 g.)**	63
C ₆ H ₅ CO ₂ CH(COCH ₃)- <i>n</i> -C ₅ H ₁₁ (13.2 g.)	CH ₃ MgBr (10.0 g.)	C ₆ H ₅ (CH ₃) ₂ COH (3.0 g.); HO(CH ₃) ₂ CCH(OH)- <i>n</i> - C ₅ H ₁₁ (6.0 g.)	496
9-Benzoxymethylcarbazole (7.62 g.)	C ₆ H ₅ MgBr (4.75 g. C ₆ H ₅ Br)	9-Benzylcarbazole; C ₆ H ₅ CO ₂ H (1.4 g.)	285

* Reaction at the boiling point of ethyl ether solution.

† Reaction at 100°.

‡ Cf. Boyd and Hatt (63), who suggest that this product is biphenyl.

§ Moderately rapid addition of ester to intermittently cooled Grignard reagent solution; ten hours reflux.

¶ Addition of ester to ice-cooled Grignard reagent solution; five hours in pressure bottle at 100°.

‡ Gradual addition of ester to Grignard reagent solution; six hours reflux.

** "Method of Stadnikoff" (398)§.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₅O₂-R (<i>cont.</i>)			
C ₆ H ₅ CO ₂ C(C ₆ H ₅) ₃ (6.0 g., 0.015 mole)	CH ₃ MgI (13.5 g., 0.098 mole CH ₃ I)	CH ₃ C(C ₆ H ₅) ₃ (2.3 g., 43%); C ₆ H ₅ CO ₂ H (1.0 g., 85%)	153
C₇H₅O₃-R			
2-HOC ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr (4 equiv.)	2-HOC ₆ H ₄ (C ₆ H ₅) ₂ COH (80%)	20
2-HOC ₆ H ₄ CO ₂ CH ₃ (30 g.)	1-C ₁₀ H ₇ MgBr (160 g. C ₁₀ H ₇ Br)	2-HOC ₆ H ₄ (1-C ₁₀ H ₇) ₂ COH	197
2-HOC ₆ H ₄ CO ₂ - <i>i</i> -C ₄ H ₉ (48.5 g.)	<i>i</i> -C ₃ H ₇ MgBr (123.0 g. C ₃ H ₇ Br)	2-HOC ₆ H ₄ (<i>i</i> -C ₃ H ₇) ₂ COH (15.0 g.)	328
3-HOC ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	3-HOC ₆ H ₄ (C ₆ H ₅) ₂ COH	20
C₇H₅O₄-R			
2,5-(HO) ₂ C ₆ H ₃ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	2,5-(HO) ₂ C ₆ H ₃ (C ₆ H ₅) ₂ COH (60%)	21
C₇H₆O₂ClN₂-R			
Ethyl 2-methyl-4-chloro-5-pyrimidineacetate	CH ₃ MgX	2-Methyl-4-chloro-5-(β-hydroxyisobutyl)pyrimidine; 2-methyl-4-chloro-5-acetonylpyrimidine	308
C₇H₆O₂N-R			
Ethyl 6-methyl-3-pyridinecarboxylate*	CH ₃ MgI	2-(6-Methyl-3-pyridyl)-2-propanol	309
C₇H₈O₂Cl-R			
Ethyl 2-chloro-2-cyclohexene-1-carboxylate	C ₆ H ₅ MgBr	α,α-Diphenyl-2-chloro-2-cyclohexene-1-methanol	297
C₇H₈O₂N-R			
Ethyl 3,5-dimethyl-2-pyrrolecarboxylate	C ₂ H ₅ MgBr	Recovered ester ("probably through enolate")	172

* 2-Methyl-5-carbethoxypyridine.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₈O₄-R₂			
<i>n</i> -C ₃ H ₇ CH=CH(CO ₂ C ₂ H ₅) ₂ (0.16 mole)	1-C ₁₀ H ₇ CH ₂ MgCl (0.21 mole C ₁₁ H ₉ Cl)	<i>n</i> -C ₃ H ₇ (1-C ₁₀ H ₇ CH ₂)CHCH(CO ₂ C ₂ H ₅) ₂ (68%)	360
<i>n</i> -C ₃ H ₇ CH=CH(CO ₂ C ₂ H ₅) ₂ (0.16 mole)	1-C ₁₀ H ₇ CH ₂ MgCl (0.21 mole C ₁₁ H ₉ Cl) + CdCl ₂ (0.20 mole)	<i>n</i> -C ₃ H ₇ (1-C ₁₀ H ₇ CH ₂)CHCH(CO ₂ C ₂ H ₅) ₂ (77%)	360
C₇H₉O₂-R			
(CH ₂) ₄ CHCO ₂ C ₂ H ₅	<i>n</i> -C ₁₀ H ₂₁ MgBr	(CH ₂) ₄ CH(<i>n</i> -C ₁₀ H ₂₁) ₂ COH (yielding 42% paraffin)	453
C₇H₉O₃-R			
Ethyl 2-oxocyclopentaneacetate*	CH ₃ MgX	2-Hydroxy-2-methylcyclopentaneacetic acid γ-lactone	385
C₇H₁₀O₂N-R			
NCC(C ₂ H ₅) ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgX†	(C ₂ H ₅) ₂ CO; (C ₂ H ₅) ₂ CHCN; (C ₂ H ₅) ₃ COH; (C ₂ H ₅) ₂ CHCO ₂ C ₂ H ₅ ; (C ₂ H ₅) ₂ CHCOC(C ₂ H ₅) ₂ CO ₂ C ₂ H ₅ ; NCC(C ₂ H ₅) ₂ C(C ₂ H ₅) ₂ OH	263
NCC(C ₂ H ₅) ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CO; (C ₂ H ₅) ₂ CHCOC(C ₂ H ₅) ₂ CO ₂ C ₂ H ₅	263
C₇H₁₀O₄-R₂			
CH ₃ (H ₃ CO ₂ CCH ₂)CH— (CH ₂) ₂ CO ₂ CH ₃	CH ₃ MgI	HO(CH ₃) ₂ CCH ₂ CH(CH ₃)(CH ₂) ₂ C(CH ₃) ₂ OH	23
C₇H₁₁O₂-R			
(CH ₂) ₅ CHCO ₂ CH ₃	CH ₃ MgI	(CH ₂) ₅ CHC(CH ₃) ₂ OH	300

* 2-Carboethoxymethylcyclopentanone.

†X = Br, I.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₁O₂-R (cont.)			
(CH ₂) ₅ CHCO ₂ C ₂ H ₅	CH ₃ MgI	(CH ₂) ₅ CH(CH ₃) ₂ COH	155
(CH ₂) ₅ CHCO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	(CH ₂) ₅ CH(C ₂ H ₅) ₂ COH	155
(CH ₂) ₅ CHCO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	(CH ₂) ₅ CH(C ₆ H ₅) ₂ COH	155
(CH ₂) ₅ CHCO ₂ C ₂ H ₅ (3 g.)	C ₆ H ₅ MgI (15 g. C ₆ H ₅ I)	(CH ₂) ₅ CH(C ₆ H ₅) ₂ COH (ca. 2 g.); (C ₆ H ₅ —) ₂	376
(CH ₂) ₅ CHCO ₂ C ₂ H ₅ (22.5 g.)	<i>t</i> -C ₄ H ₉ C≡CMgBr (24 g. <i>t</i> -C ₄ H ₉ C≡CH)	(CH ₂) ₅ CH(<i>t</i> -C ₄ H ₉ C≡C) ₂ COH (70%)	126
(CH ₂) ₅ CHCO ₂ C ₂ H ₅ (31 g.)	(CH ₂) ₅ CHMgCl (100 g. C ₆ H ₁₁ Cl)	[(CH ₂) ₅ CH—] ₂ (6 g.); [(CH ₂) ₅ CH] ₂ CO (27 g.); [(CH ₂) ₅ CH] ₃ COH (ca. 4 g.)	303
(CH ₂) ₅ CHCO ₂ C ₂ H ₅	(CH ₂) ₅ CHMgBr	[(CH ₂) ₅ CH] ₂ CO; [(CH ₂) ₅ CH] ₂ CHOH	296
(CH ₂) ₅ CHCO ₂ CH ₂ CH=CH ₂	C ₆ H ₅ MgBr	(CH ₂) ₂ CH(C ₆ H ₅) ₂ COH	6
C₇H₁₁O₃-R			
(CH ₂) ₅ C(OH)CO ₂ CH ₃	CH ₃ MgI (4 equiv.)	(CH ₂) ₅ C(OH)C(CH ₃) ₂ OH (94%)	280,413
(CH ₂) ₅ C(OH)CO ₂ CH ₃ (20 g.)	C ₆ H ₅ MgBr (80 g. C ₆ H ₅ Br)	(CH ₂) ₅ C(OH)C(C ₆ H ₅) ₂ OH (27 g.)	280
C₇H₁₂O₂N-R			
(CH ₂) ₅ C(NH ₂)CO ₂ C ₂ H ₅	CH ₃ MgI (3 equiv.)	(CH ₂) ₅ C(NH ₂)COCH ₃	128
(CH ₂) ₅ C(NH ₂)CO ₂ C ₂ H ₅	CH ₃ MgI (5 equiv.)	(CH ₂) ₅ C(NH ₂)C(CH ₃) ₂ OH; (CH ₂) ₅ C(NH ₂)COCH ₃ ; 8,16-dimethyl-7,5-diazadispiro[5.2.5.2]hexadeca- 7,15-diene	128
(CH ₂) ₅ C(NH ₂)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr (3 equiv.)	(CH ₂) ₅ C(NH ₂)COC ₂ H ₅	128
(CH ₂) ₅ C(NH ₂)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr (3 equiv.)	(CH ₂) ₅ C(NH ₂)COC ₆ H ₅	128
C₇H₁₃O₂-R			
<i>n</i> -C ₆ H ₁₃ CO ₂ C ₂ H ₅	CH ₃ MgX (2 equiv.)	<i>n</i> -C ₆ H ₁₃ (CH ₃) ₂ COH (80–85%); corresponding olefin (ca. 1%)	259
<i>n</i> -C ₆ H ₁₃ CO ₂ C ₂ H ₅	<i>t</i> -C ₄ H ₉ MgCl	(<i>n</i> -C ₆ H ₁₃) ₂ CO	329

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₃O₂-R (cont.)			
(+)- <i>n</i> -C ₃ H ₇ CH(C ₂ H ₅)CO ₂ C ₂ H ₅	CH ₃ MgI	After dehydr'n and hydrogen'n, (+)-CH ₃ (C ₂ H ₅)(<i>i</i> -C ₅ H ₁₁)CH	241
CH ₃ (C ₂ H ₅) ₂ CCO ₂ C ₂ H ₅	CH ₃ MgBr	Addition (45%); enolization (25%)*	457
CH ₃ (C ₂ H ₅) ₂ CCO ₂ - <i>n</i> -C ₄ H ₉	CH ₃ MgBr	Addition (60%); enolization (22%)*	457
C₈H₄O₃-N-R			
Ethyl α-cyano-β-(2-furyl)acrylate (40 g.)	<i>n</i> -C ₃ H ₇ MgBr (70 g. C ₃ H ₇ Br)	<i>n</i> -C ₃ H ₇ (α-C ₄ H ₃ O)CHCH(CN)CO ₂ C ₂ H ₅ (40 g., 82%)	264
Ethyl α-cyano-β-(2-furyl)acrylate (20 g.)	<i>i</i> -C ₄ H ₉ MgCl (27 g. C ₄ H ₉ Cl)	<i>i</i> -C ₄ H ₉ (α-C ₄ H ₃ O)CHCH(CN)CO ₂ C ₂ H ₅ (24 g.)	264
C₈H₄O₄-R₂			
C ₆ H ₄ -1,2-(CO ₂ CH ₃) ₂	C ₂ H ₅ MgI	3,3-Diethylphthalide	382
C ₆ H ₅ -1,2-(CO ₂ CH ₃) ₂	C ₆ H ₅ MgBr (large excess)	1,3,3-Triphenyl-1-phthalanol (90%)†	145,146
C ₆ H ₄ -1,2-(CO ₂ CH ₃) ₂ (18.0 g.)	C ₆ H ₅ MgBr (83.7 g. C ₆ H ₅ Br)	C ₂₆ H ₁₈ O, m. 192–193°†§	167; cf. 382
C ₆ H ₅ -1,2-(CO ₂ C ₂ H ₅) ₂	CH ₃ MgI (4 equiv.)	1,1-Dimethyl-3-methylenephthalan¶	382
C ₆ H ₅ -1,2-(CO ₂ C ₂ H ₅) ₂	C ₂ H ₅ MgX†	3,3-Diethylphthalide	382

* "Grignard machine" study; according to Whitmore and Lewis (457), the apparent enolization of these esters is actually that of the ketones formed by reaction with the Grignard reagent (see textual discussion).

† Pérard, *Ann. chim.*, [9], 7, 344, footnote (1917), suggests that the product of Guyot and Catel (145) [and hence the corresponding product of Howell (167)] should be formulated as 2-C₆H₅COC₆H₄C(C₆H₅)₂OH.

‡ Purification by steam-distillation; recovery by distillation at reduced pressure.

§ According to Howell (167), this product [doubtless 10,10-diphenyl-9-anthrone—see Barnett *et al.* (25)] is the dehydrate of the "1,3,3-triphenyl-1-phthalanol" of Guyot and Catel (145), and is identical with the "1,1-diphenyl-3-phenylenephthalan" of Shibata (382).

¶ Possibly 2-CH₃COC₆H₄C(CH₃)=CH₂ [cf. Barnett *et al.* (25)].

† X = Br, I.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₄O₄-R₂ (cont.)			
C ₆ H ₅ -1,2-(CO ₂ C ₂ H ₅) ₂ (10.0 g.)	Pyrryl-MgBr (6.7 g. pyrrole)	3-(2-Pyrroleninylidene)phthalide	129
C ₆ H ₄ -1,2-(CO ₂ C ₂ H ₅) ₂ (18.0 g.)	C ₆ H ₅ MgBr (83.7 g. C ₆ H ₅ Br)	C ₂₆ H ₁₈ O, m. 192–193°*†	167
C ₆ H ₄ -1,2-(CO ₂ C ₂ H ₅) ₂ (23.0 g.)	C ₆ H ₅ MgBr (125.6 g. C ₆ H ₅ Br)	1,3,3-Triphenyl-1-phthalanol‡§	167
C ₆ H ₄ -1,2-(CO ₂ C ₂ H ₅) ₂	C ₆ H ₅ MgBr (4 equiv.)	10,10-Diphenyl-9-anthrone	25; c/.382
C ₆ H ₄ -1,2-(CO ₂ C ₂ H ₅) ₂	C ₆ H ₅ CH ₂ MgCl	3,3-Dibenzylphthalide	382
C ₆ H ₄ -1,2-(CO ₂ <i>n</i> -C ₄ H ₉) ₂ (69.5 g.)	C ₆ H ₅ MgBr (39.0 g. C ₆ H ₅ Br)	2-C ₆ H ₅ COC ₆ H ₄ CO ₂ - <i>n</i> -C ₄ H ₉ (yielding 7.0 g. acid; 3,3-diphenylphthalide; (C ₆ H ₅ —) ₂ (2.0 g.)	233
C ₆ H ₄ -1,3-(CO ₂ CH ₃) ₂ (20 g.)	C ₆ H ₅ MgBr (65 g. C ₆ H ₅ Br)	C ₆ H ₄ -1,3-[C(C ₆ H ₅) ₂ OH] ₂ (40 g., crude)	403
C ₆ H ₄ -1,4-(CO ₂ CH ₃) ₂ (15 g.)	C ₆ H ₅ MgBr (50 g. C ₆ H ₅ Br)	C ₆ H ₄ -1,4-[C(C ₆ H ₅) ₂ OH] ₂ (25 g., crude)	415,483
C₈H₄O₅-R			
Diethyl furfurylidenemalonate (25 g.)	<i>i</i> -C ₄ H ₉ MgCl (27 g. C ₄ H ₉ Cl)	<i>i</i> -C ₄ H ₉ (α -C ₄ H ₃ O)CHCH(CO ₂ C ₂ H ₅) ₂ (22 g., 71%)	264
Diethyl furfurylidenemalonate (40 g.)	<i>i</i> -C ₅ H ₁₁ MgBr (43 g. C ₅ H ₁₁ Br)	<i>i</i> -C ₅ H ₁₁ (α -C ₄ H ₃ O)CHCH(CO ₂ C ₂ H ₅) ₂ (45 g., 87%)	264
Diethyl furfurylidenemalonate (15 g.)	C ₆ H ₅ MgBr (28 g. C ₆ H ₅ Br)	C ₆ H ₅ (α -C ₄ H ₃ O)CHCH(CO ₂ C ₂ H ₅) ₂ (15 g., 77%)	264

* Purification by steam-distillation; recovery by distillation at reduced pressure.

† According to Howell (167), this product [doubtless 10,10-diphenyl-9-anthrone—see Barnett *et al.* (25)] is the dehydrate of the "1,3,3-triphenyl-1-phthalanol" of Guyot and Catel (145), and is identical with the "1,1-diphenyl-3-phenylenephthalan" of Shibata (382).

‡ P  rard, *Ann.chim.*, [9], 7, 344, f'note (1917), suggests that the product of Guyot and Catel (145) [and hence the corresponding product of Howell (167)] should be formulated as 2-C₆H₅COC₆H₄C(C₆H₅)₂OH.

§ Purification and recovery by crystallization.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₅O₄-R			
3,4-CH ₂ O ₂ =C ₆ H ₃ CO ₂ CH ₃	CH ₃ MgI (4 equiv.)	3,4-CH ₂ O ₂ =C ₆ H ₃ C(CH ₃)=CH ₂	33
3,4-CH ₂ O ₂ =C ₆ H ₃ CO ₂ CH ₃	C ₆ H ₅ MgBr	3,4-CH ₂ O ₂ =C ₆ H ₃ (C ₆ H ₅) ₂ COH	62
2-HO ₂ CC ₆ H ₄ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	3,3-Diethylphthalide	382
2-HO ₂ CC ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	"1,1-Diphenyl-3-phenylenephthalan"*	382
2-HO ₂ CC ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl	3,3-Dibenzylphthalide; 1,1-dibenzyl-3-benzylidenephthalan†	382
C₈H₆O₂Br-R			
C ₆ H ₅ CHBrCO ₂ C ₂ H ₅	C ₆ H ₅ CH(CO ₂ Na)MgCl‡	C ₆ H ₅ CH(CO ₂ H)CH(C ₆ H ₅)CO ₂ C ₂ H ₅ (38.4%)	405
C₈H₆O₂Cl-R			
4-ClC ₆ H ₄ CH ₂ CO ₂ C ₂ H ₅	<i>i</i> -C ₃ H ₇ MgCl	4-ClC ₆ H ₄ CH ₂ COCH(C ₆ H ₅)CO ₂ C ₂ H ₅ (93%)	183
C₈H₇O₂-R			
C ₆ H ₅ CH ₂ CO ₂ C ₂ H ₅	CH ₃ MgI	C ₆ H ₅ CH ₂ (CH ₃) ₂ COH	204
C ₆ H ₅ CH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgI	C ₆ H ₅ CH ₂ (C ₂ H ₅) ₂ COH (65%)	204
C ₆ H ₅ CH ₂ CO ₂ C ₂ H ₅ (0.1 mole)	<i>i</i> -C ₃ H ₇ MgCl (0.15 mole)	C ₆ H ₅ CH ₂ COCH(C ₆ H ₅)CO ₂ C ₂ H ₅ ; C ₃ H ₈	183
C ₆ H ₅ CH ₂ CO ₂ C ₂ H ₅ (49.2 g., 0.3 mole)	<i>i</i> -C ₃ H ₇ MgBr (0.5 mole)	C ₆ H ₅ CH ₂ COCH(C ₆ H ₅)CO ₂ C ₂ H ₅ (39.5 g., 94%); "saturated gas"	87
C ₆ H ₅ CH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ (C ₆ H ₅) ₂ COH ("good yield")	205
C ₆ H ₅ CH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl	(C ₆ H ₅ CH ₂) ₃ COH	205

* Doubtless 10,10-diphenyl-9-anthrone.

† Possibly 2-C₆H₅CH₂COC₆H₄C(CH₂C₆H₅)=CHC₆H₅.

‡ In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₇O₂-R (cont.)			
C ₆ H ₅ CH ₂ CO ₂ C ₂ H ₅ + 2-CH ₃ C ₆ H ₄ CO ₂ C ₂ H ₅ (0.1 mole each)	C ₆ H ₅ CH ₂ MgCl (0.2 mole)	2-CH ₃ C ₆ H ₄ CO ₂ C ₂ H ₅ (72% recovery); C ₆ H ₅ CH ₂ CO ₂ H (1 g.); (C ₆ H ₅ CH ₂) ₃ COH (corresponding to 71% conversion of C ₆ H ₅ CH ₂ CO ₂ C ₂ H ₅)	10
C ₆ H ₅ CH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	(C ₆ H ₅ CH ₂) ₃ COH	364
2-CH ₃ C ₆ H ₄ CO ₂ CH ₃ (13.6 g.)	C ₆ H ₅ MgBr (31.0 g. C ₆ H ₅ Br)	2-CH ₃ C ₆ H ₄ (C ₆ H ₅) ₂ COH (11.0 g.)	48
2-CH ₃ C ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	2-CH ₃ C ₆ H ₄ (C ₆ H ₅) ₂ COH (39.7%); [C ₆ H ₅ (2-CH ₃ C ₆ H ₄)COH—] ₂ (13.6%)*	63
2-CH ₃ C ₆ H ₄ CO ₂ C ₂ H ₅ (7.5 g.)	C ₆ H ₅ MgBr	[C ₆ H ₅ (2-CH ₃ C ₆ H ₄)COH—] ₂ (0.02 g., 0.26%); 2-CH ₃ C ₆ H ₄ (C ₆ H ₅) ₂ COH (1.29 g.); C ₂ H ₅ OC(C ₆ H ₅) ₂ C ₆ H ₄ -2-CH ₃ (0.77 g.)†	63
2-CH ₃ C ₆ H ₄ CO ₂ C ₂ H ₅ (7.5 g.)	C ₆ H ₅ MgBr (16.2 g. C ₆ H ₅ Br) + excess Mg	[C ₆ H ₅ (2-CH ₃ C ₆ H ₄)COH—] ₂ (3.62 g., 38%); 2-CH ₃ C ₆ H ₄ (C ₆ H ₅) ₂ COH (2.92 g., 23.3%)‡	63
2-CH ₃ C ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl (excess)	No dibenzyl- <i>o</i> -tolylmethanol; liquid believed to be benzyl- <i>o</i> -tolyl ketone	10
2-CH ₃ C ₆ H ₄ CO ₂ C ₂ H ₅ (6.7 g.)	2-CH ₃ C ₆ H ₄ MgBr (16.5 g. C ₇ H ₇ Br) + Mg	[(2-CH ₃ C ₆ H ₄) ₂ COH—] ₂ (5.2%); (2-CH ₃ C ₆ H ₄) ₂ CHOH (0.71 g.)	63
2-CH ₃ C ₆ H ₄ CO ₂ CH ₂ CH=CH ₂ (15.0 g.)	C ₆ H ₅ MgBr (30 g. C ₆ H ₅ Br)	2-CH ₃ C ₆ H ₄ (C ₆ H ₅) ₂ COH (15.4 g.)	4
3-CH ₃ C ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr	3-CH ₃ C ₆ H ₄ (C ₆ H ₅) ₂ COH (81%)	48
3-CH ₃ C ₆ H ₄ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	3-CH ₃ C ₆ H ₄ (C ₆ H ₅) ₂ COH (5.3 g.); (C ₆ H ₅ —) ₂ (1.2 g.)	2
4-CH ₃ C ₆ H ₄ CO ₂ CH ₃ (13.8 g.)	C ₆ H ₅ MgBr (31.0 g. C ₆ H ₅ Br)	4-CH ₃ C ₆ H ₄ (C ₆ H ₅) ₂ COH (20.0 g.)	484
4-CH ₃ C ₆ H ₄ CO ₂ CH ₃	4-CH ₃ C ₆ H ₄ MgI	(4-CH ₃ C ₆ H ₄) ₃ COH	293
4-CH ₃ C ₆ H ₄ CO ₂ C ₂ H ₅ (37.1 g.)	4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ MgBr (106.5 g. C ₁₀ H ₁₃ Br)	4-CH ₃ C ₆ H ₄ (4- <i>t</i> -C ₄ H ₉ C ₆ H ₄) ₂ COH (24 g.)	257

* Addition of Et₂O-ester solution to Grignard reagent solution.

† Addition of Et₂O-ester solution to *filtered* Grignard reagent solution.

‡ Gradual addition of filtered Grignard reagent solution to stirred Et₂O-ester solution and excess Mg; one hour reflux. Reaction under N₂.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₇O₃-R			
C ₆ H ₅ OCH ₂ CO ₂ C ₂ H ₅	CH ₃ MgX	C ₆ H ₅ OCH ₂ (CH ₃) ₂ COH (70%)	408
C ₆ H ₅ OCH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	C ₆ H ₅ OCH ₂ (C ₂ H ₅) ₂ COH	31
C ₆ H ₅ OCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ OCH ₂ (C ₆ H ₅) ₂ COH (71%)	408
C ₆ H ₅ OCH ₂ CO ₂ C ₂ H ₅	4-CH ₃ C ₆ H ₄ MgBr (2 equiv.)	C ₆ H ₅ OCH ₂ (4-CH ₃ C ₆ H ₄) ₂ COH (65%)	408
2-CH ₃ OC ₆ H ₄ CO ₂ CH ₃	CH ₃ MgI (2 equiv.)	2-CH ₃ OC ₆ H ₄ (CH ₃) ₂ COH	32
2-CH ₃ OC ₆ H ₄ CO ₂ CH ₃	CH ₃ MgI (3 equiv.)	2-CH ₃ C ₆ H ₄ C(CH ₃)=CH ₂	32
2-CH ₃ OC ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr	2-CH ₃ OC ₆ H ₄ (C ₆ H ₅) ₂ COH	20
3-CH ₃ OC ₆ H ₄ CO ₂ C ₂ H ₅	CH ₃ MgI (2 equiv.)	3-CH ₃ OC ₆ H ₄ (CH ₃) ₂ COH	32
3-CH ₃ OC ₆ H ₄ CO ₂ C ₂ H ₅	CH ₃ MgI (3 equiv.)	3-CH ₃ OC ₆ H ₄ C(CH ₃)=CH ₂	32
4-CH ₃ OC ₆ H ₄ CO ₂ R*	CH ₃ MgI (2 or 3 equiv.)	4-CH ₃ OC ₆ H ₄ C(CH ₃)=CH ₂ (ca. 50%); dimer	32
4-CH ₃ OC ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ CH ₂ MgCl	4-CH ₃ OC ₆ H ₄ (C ₆ H ₅ CH ₂) ₂ COH (75%)	208
4-CH ₃ OC ₆ H ₄ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr (3 equiv.)	4-CH ₃ OC ₆ H ₄ (C ₂ H ₅) ₂ COH	445
2-HO-3-CH ₃ C ₆ H ₃ CO ₂ CH ₃	CH ₃ MgI (4 equiv.)	2-HO-3-CH ₃ C ₆ H ₃ C(CH ₃)=CH ₂	34
2-HO-3-CH ₃ C ₆ H ₃ CO ₂ CH ₃	CH ₃ MgI (3.5 equiv.)	2-HO-3-CH ₃ C ₆ H ₃ C(CH ₃) ₂ OH; 2-HO-3-CH ₃ C ₆ H ₃ C(CH ₃)=CH ₂	144
2-HO-4-CH ₃ C ₆ H ₃ CO ₂ CH ₃	CH ₃ MgI (3.5 equiv.)	2-HO-4-CH ₃ C ₆ H ₃ C(CH ₃) ₂ OH; 2-HO-4-CH ₃ C ₆ H ₃ C(CH ₃)=CH ₂	144
2-HO-5-CH ₃ C ₆ H ₃ CO ₂ CH ₃	CH ₃ MgI (3.5 equiv.)	2-HO-5-CH ₃ C ₆ H ₃ C(CH ₃) ₂ OH	144
C ₆ H ₅ CH(OH)CO ₂ CH ₃ (3 g.)	C ₆ H ₅ MgBr (11 g. C ₆ H ₅ Br)	C ₆ H ₅ CH(OH)C(C ₆ H ₅) ₂ OH (4 g.)	1
C ₆ H ₅ CH(OH)CO ₂ CH ₃ (16.6 g.)	C ₆ H ₅ CH ₂ MgCl (63.5 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH(OH)C(CH ₂ C ₆ H ₅) ₂ OH (26 g., 81%)	312
C ₆ H ₅ CH(OH)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	C ₆ H ₅ CH(OH)C(C ₂ H ₅) ₂ OH	419
C ₆ H ₅ CH(OH)CO ₂ C ₂ H ₅ (40 g.)	<i>n</i> -C ₃ H ₇ MgBr (from 90 g. bromide)	C ₆ H ₅ CH(OH)C(<i>n</i> -C ₃ H ₇) ₂ OH	420
C ₆ H ₅ CH(OH)CO ₂ C ₂ H ₅ (22.5 g.)	<i>n</i> -C ₄ H ₉ MgI (95.0 g. C ₄ H ₉ I)	C ₆ H ₅ CH(OH)C(<i>n</i> -C ₄ H ₉) ₂ OH	420

* R = CH₃, C₂H₅.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₇O₈-R (<i>cont.</i>)			
C ₆ H ₅ CH(OH)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr (3.5 equiv.)	C ₆ H ₅ CH(OH)C(C ₆ H ₅) ₂ OH	420
C ₆ H ₅ CH(OH)CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	C ₆ H ₅ CH(OH)C(CH ₂ C ₆ H ₅) ₂ OH (54%)	43
DL-C ₆ H ₅ CH(OH)CO ₂ C ₂ H ₅	2-CH ₃ C ₆ H ₄ MgBr (4.5 equiv.)	Unstable oil	362,408
DL-C ₆ H ₅ CH(OH)CO ₂ C ₂ H ₅	3-CH ₃ C ₆ H ₄ MgBr (4 equiv.)	C ₆ H ₅ CH(OH)C(C ₆ H ₄ -3-CH ₃) ₂ OH	362
D(-)-C ₆ H ₅ CH(OH)CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr (4 equiv.)	D(+)-C ₆ H ₅ CH(OH)C(<i>n</i> -C ₃ H ₇) ₂ OH	269
D(-)-C ₆ H ₅ CH(OH)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	D(+)-C ₆ H ₅ CH(OH)C(C ₆ H ₅) ₂ OH	362
D(-)-C ₆ H ₅ CH(OH)CO ₂ C ₂ H ₅	4-CH ₃ C ₆ H ₄ MgBr (5 equiv.)	D(+)-C ₆ H ₅ CH(OH)C(C ₆ H ₄ - <i>n</i> -CH ₃) ₂ OH	362
L(-)-C ₆ H ₅ CH(OH)CO ₂ CH ₃	CH ₃ MgI	L(-)-C ₆ H ₅ CH(OH)C(CH ₃) ₂ OH	278
L(-)-C ₆ H ₅ CH(OH)CO ₂ CH ₃	C ₆ H ₅ MgBr	L(+)-C ₆ H ₅ CH(OH)C(C ₆ H ₅) ₂ OH	278
L(-)-C ₆ H ₅ CH(OH)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr (3.5 equiv.)	L(-)-C ₆ H ₅ CH(OH)C(C ₆ H ₅) ₂ OH	269
C₈H₇O₄-R			
3-CH ₃ O-4-HOC ₆ H ₃ CO ₂ C ₂ H ₅	CH ₃ MgI (3 equiv.)	3-CH ₃ O-4-HOC ₆ H ₃ C(CH ₃) ₂ OH; dimer	33
C₈H₈O₂NS-R			
C ₆ H ₅ SO ₂ HNCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ SO ₂ HNCH ₂ (C ₆ H ₅) ₂ COH (51%)	45
C₈H₉O₂ClN-R			
HCl·HN(C ₆ H ₅)CH ₂ CO ₂ C ₂ H ₅	CH ₃ MgBr	C ₆ H ₅ HNCH ₂ (CH ₃) ₂ COH	45
C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	C ₆ H ₅ CH(NH ₂)C(C ₂ H ₅) ₂ OH (65%)	416
C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (16.6 g.)	C ₆ H ₅ MgBr (145.0 g. C ₆ H ₅ Br)	C ₆ H ₅ CH(NH ₂)C(C ₆ H ₅) ₂ OH (11.0 g., 49%)	273
C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ CH(NH ₂)C(C ₆ H ₅) ₂ OH (72%)	416
C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (10.0 g.)	C ₆ H ₅ CH ₂ MgCl (52.5 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH(NH ₂)C(CH ₂ C ₆ H ₅) ₂ OH	274
C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	C ₆ H ₅ CH(NH ₂)C(CH ₂ C ₆ H ₅) ₂ OH (61%)	416

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₉O₂ClN·R (<i>cont.</i>)			
C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (6.2 g.)	1-C ₁₀ H ₇ MgBr (75.0 g. C ₁₀ H ₇ Br)	No identified product	273
DL-C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (10 g.)	CH ₃ MgI (59 g. CH ₃ I)	DL-C ₆ H ₅ CH(NH ₂)C(CH ₃) ₂ OH	269; <i>cf.</i> 273
DL-C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (5 g.)	<i>n</i> -C ₃ H ₇ MgBr (26 g. C ₃ H ₇ Br)	DL-C ₆ H ₅ CH(NH ₂)C(<i>n</i> -C ₃ H ₇) ₂ OH	269
D-C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (6 g.)	C ₆ H ₅ MgBr (52 g. C ₆ H ₅ Br)	D-C ₆ H ₅ CH(NH ₂)C(C ₆ H ₅) ₂ OH (2 g., crude)	275
D-C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (12 g.)	C ₆ H ₅ CH ₂ MgCl (63 g. C ₇ H ₇ Cl)	D-C ₆ H ₅ CH(NH ₂)C(CH ₂ C ₆ H ₅) ₂ OH (8.2 g.)	271
L-C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (10 g.)	C ₂ H ₅ MgBr (51 g. C ₂ H ₅ Br)	L-C ₆ H ₅ CH(NH ₂)C(C ₂ H ₅) ₂ OH	269
L-C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (5 g.)	<i>n</i> -C ₃ H ₇ MgBr (26 g. C ₃ H ₇ Br)	L-C ₆ H ₅ CH(NH ₂)C(<i>n</i> -C ₃ H ₇) ₂ OH	269
L-C ₆ H ₅ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅ (5 g.)	C ₆ H ₅ MgBr (12 equiv.)	L-C ₆ H ₅ CH(NH ₂)C(C ₆ H ₅) ₂ OH (6 g., crude)	275
C₈H₉O₃-R			
Methyl 5-isopropyl-2-furoate	CH ₃ MgBr (2 equiv.)	2-(2-Hydroxy-2-propyl)-5-isopropylfuran (90%)	14
C₈H₁₀O₄-R₂			
(CH ₃) ₂ C=CHCH ₂ CH(CO ₂ C ₂ H ₅) ₂	CH ₃ MgBr	Recovered ester (<i>quant.</i>)	386
Diethyl hexahydrophthalate	CH ₃ MgI	Cyclohexane-1,2-bisdimethylmethanol	465
C₈H₁₂O₄-R₂			
[—(CH ₂) ₃ CO ₂ CH ₃] ₂	C ₆ H ₅ MgBr	[—(CH ₂) ₃ C(C ₆ H ₅) ₂ OH] ₂ (yielding 80–90% alkene)	377
[—(CH ₂) ₃ CO ₂ C ₂ H ₅] ₂ (0.2 mole)	<i>t</i> -C ₄ H ₉ MgCl (2.5 mole)	[—(CH ₂) ₃ C(<i>t</i> -C ₄ H ₉) ₂ OH] ₂	336
C₈H₁₃O₆-R			
"Methyl 3,4,5-trimethyl- α - ketoarabonate" (20.20 g.)	CH ₃ MgI (13.06 g. CH ₃ I)	"Methyl 3,4,5-trimethylsaccharinate" (60%)	123

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₅O₂-R			
<i>n</i> -C ₇ H ₁₅ CO ₂ CH ₃	C ₆ H ₅ MgBr	<i>n</i> -C ₇ H ₁₅ (C ₆ H ₅) ₂ COH (yielding 80-90% alkene)	377
<i>n</i> -C ₇ H ₁₅ CO ₂ C ₂ H ₅	<i>n</i> -C ₈ H ₁₇ MgBr	<i>n</i> -C ₇ H ₁₅ (<i>n</i> -C ₈ H ₁₇) ₂ COH; dehydr'n product	339
CH ₃ (<i>i</i> -C ₅ H ₁₁)CHCO ₂ CH ₃	CH ₃ MgI	CH ₃ (<i>i</i> -C ₅ H ₁₁)CHC(CH ₃) ₂ OH	23
C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CHCO ₂ CH ₂ CH=CH ₂ (31.5 g.)	C ₆ H ₅ MgBr (36.6 g. C ₆ H ₅ Br)	C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CHCO ₂ H (30%); C ₆ H ₅ CH ₂ CH=CH ₂ (26%); C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CHC(C ₆ H ₅) ₂ OH (49%); C ₂ H ₅ (<i>n</i> -C ₄ H ₉)C=C(C ₆ H ₅) ₂	6
D- <i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇)CHCO ₂ C ₂ H ₅	CH ₃ MgI	After dehydr'n and hydrogen'n D-CH ₃ (<i>n</i> -C ₃ H ₇)(<i>i</i> - C ₅ H ₁₁)CH	241
(C ₂ H ₅) ₃ CCO ₂ C ₂ H ₅	CH ₃ MgBr	Addition (0%); enolization (0%)*	457
C₉H₅O₂-R			
C ₆ H ₅ C≡CCO ₂ C ₂ H ₅	4-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ C≡C(4-CH ₃ C ₆ H ₄) ₂ COH	100
C₉H₅O₃-R			
Ethyl 2-benzofurancarboxylate	CH ₃ MgBr	2-Isopropenylbenzofuran (54%)	14
C₉H₆O₂Br-R			
C ₆ H ₅ CH=CBrcO ₂ C ₂ H ₅	CH ₃ MgI	C ₆ H ₅ CH=CBrc(CH ₃) ₂ OH	219
C ₆ H ₅ CH=CBrcO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCHBrCO ₂ C ₂ H ₅ (<i>ca.</i> 70%); (C ₆ H ₅) ₂ CHCHBrCOC ₆ H ₅	219
C₉H₇O₂-R			
C ₆ H ₅ CH=CHCO ₂ CH ₃	CH ₃ MgI	C ₆ H ₅ CH=CHC(CH ₃) ₂ OH; [C ₆ H ₅ CH=CHC(CH ₃) ₂ O (?)] (<5%)	216
C ₆ H ₅ CH=CHCO ₂ CH ₃	<i>l</i> -C ₄ H ₉ MgCl	C ₆ H ₅ CH=CHCO ₂ H (3%)	154

* "Grignard machine" study.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₇O₂-R (cont.)			
C ₆ H ₅ CH=CHCO ₂ CH ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH ₂ CO ₂ CH ₃ ; (C ₆ H ₅) ₂ CHCH ₂ COC ₆ H ₅ *	216,211
C ₆ H ₅ CH=CHCO ₂ CH ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH(CO ₂ CH ₃)COCH ₂ CH(C ₆ H ₅) ₂ ; (C ₆ H ₅) ₂ CHCH(COC ₆ H ₅)COCH ₂ CH(C ₆ H ₅) ₂ †	218
C ₆ H ₅ CH=CHCO ₂ C ₆ H ₅	C ₆ H ₅ MgBr (1 equiv.)	(C ₆ H ₅) ₂ CHCH(CO ₂ C ₆ H ₅)COCH ₂ CH(C ₆ H ₅) ₂ ‡	218
C ₆ H ₅ CH=CHCO ₂ C ₆ H ₅ (22.4 g.)	C ₆ H ₅ MgBr (3 equiv.)	(C ₆ H ₅) ₂ CHCH ₂ CO ₂ C ₆ H ₅ ; (C ₆ H ₅) ₂ CHCH ₂ COC ₆ H ₅ ; (C ₆ H ₅ —) ₂ §	218
C ₆ H ₅ CH=CHCO ₂ - <i>t</i> -C ₄ H ₉	CH ₃ MgI	No product isolated	154
C ₆ H ₅ CH=CHCO ₂ - <i>t</i> -C ₄ H ₉	C ₂ H ₅ MgBr	No product isolated	154
C ₆ H ₅ CH=CHCO ₂ - <i>t</i> -C ₄ H ₉ (20.4 g., 0.1 mole)	Butenyl-MgBr (0.19 mole)	No appreciable 1,4 addition	472
C ₆ H ₅ CH=CHCO ₂ - <i>t</i> -C ₄ H ₉ (20.4 g., 0.1 mole)	<i>n</i> -C ₄ H ₉ MgBr (0.2 mole)	<i>n</i> -C ₄ H ₉ (C ₆ H ₅)CHCH ₂ CO ₂ - <i>t</i> -C ₄ H ₉ (8.8 g., 43%)	472
C ₆ H ₅ CH=CHCO ₂ - <i>t</i> -C ₄ H ₉ (23.5 g., 0.115 mole)	C ₆ H ₅ MgBr (46.1 g., 0.23 mole C ₆ H ₅ Br)	(C ₆ H ₅) ₂ CHCH ₂ CO ₂ - <i>t</i> -C ₄ H ₉ (15 g., 44%)	117
C ₆ H ₅ CH=CHCO ₂ - <i>t</i> -C ₄ H ₉ (35.0 g., 0.172 mole)	C ₆ H ₅ MgBr (5.1 g., 0.21 mole Mg)	(C ₆ H ₅) ₂ CHCH ₂ CO ₂ - <i>t</i> -C ₄ H ₉ (36.5 g., 76%)	154
H ₂ C=C(C ₆ H ₅)CO ₂ CH ₃ (4.0 g.)	CH ₃ MgI (14.0 g. CH ₃ I)	DL-C ₂ H ₅ (C ₆ H ₅)CHCOCH ₃ (1.8 g.)	276
C₉H₇O₂Br₂-R			
C ₆ H ₅ CHBrCHBrCO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH ₂ CO ₂ C ₂ H ₅ ; (C ₆ H ₅) ₂ CHCH ₂ COC ₆ H ₅	219
C₉H₇O₄-R			
Ethyl α-acetyl-β-(2-furyl)acrylate (25 g.)	C ₂ H ₅ MgI (45 g. C ₂ H ₅ I)	C ₂ H ₅ (α-C ₄ H ₃ O)CHCH(COCH ₃)CO ₂ C ₂ H ₅ (17 g.)	264

* Dropwise addition of dilute Et₂O-ester solution to agitated Grignard reagent solution at -10°; two hours in freezing mixture; one hour at room temperature.

† Slow addition of Grignard reagent solution to cooled Et₂O-ester solution.

‡ Slow addition of Grignard reagent solution to Et₂O-ester solution; overnight standing.

§ Slow addition of dilute Et₂O-ester solution to strongly cooled Grignard reagent solution.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₇O₄-R (cont.)			
Ethyl α -acetyl- β -(2-furyl)acrylate (25 g.)	<i>n</i> -C ₃ H ₇ MgBr (36 g. C ₃ H ₇ Br)	<i>n</i> -C ₃ H ₇ (α -C ₄ H ₃ O)CHCH(COCH ₃)CO ₂ C ₂ H ₅ (16 g., 55%)	264
Ethyl α -acetyl- β -(2-furyl)acrylate (20 g.)	C ₆ H ₅ MgBr (42 g. C ₆ H ₅ Br)	C ₆ H ₅ (α -C ₄ H ₃ O)CHCH(COCH ₃)CO ₂ C ₂ H ₅ (15 g., 52%)	264
C₉H₇O₅-R			
3,4-CH ₂ O ₂ =C ₆ H ₃ CH(OH)CO ₂ C ₂ H ₅	CH ₃ MgI (4 equiv.)	3,4-CH ₂ O ₂ =C ₆ H ₃ CH(OH)C(CH ₃) ₂ OH	422
C₉H₈O₃N-R			
C ₆ H ₅ COHNCH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	C ₆ H ₅ COHNCH ₂ C(C ₂ H ₅) ₂ OH (76%)	524
C ₆ H ₅ COHNCH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	C ₆ H ₅ COHNCH ₂ C(C ₂ H ₅) ₂ OH (81%)*	524
C ₆ H ₅ COHNCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ COHNCH ₂ C(C ₆ H ₅) ₂ OH (63%)	524
C₉H₉O₂-R			
C ₆ H ₅ (CH ₂) ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr (2 equiv.)	C ₆ H ₅ (CH ₂) ₂ C(C ₆ H ₅) ₂ OH (90%)	224
C ₆ H ₅ (CH ₂) ₂ CO ₂ C ₂ H ₅ (32 g.)	C ₆ H ₅ CH ₂ MgCl (51 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CH ₂ C(C ₆ H ₅ CH ₂) ₂ COH (25-27 g.)	310
C₉H₉O₃-R			
DL-C ₆ H ₅ CH(OCH ₃)CO ₂ CH ₃	C ₆ H ₅ MgBr	DL-C ₆ H ₅ CH(OCH ₃)C(C ₆ H ₅) ₂ OH	278
(-)-C ₆ H ₅ CH(OCH ₃)CO ₂ CH ₃ (5 g.)	C ₆ H ₅ MgBr (13.2 g. C ₆ H ₅ Br)	(+)-C ₆ H ₅ CH(OCH ₃)C(C ₆ H ₅) ₂ OH (9 g., crude)	278
DL-C ₆ H ₅ CH(CH ₂ OH)CO ₂ CH ₃ (8.7 g.)	CH ₃ MgI (34.5 g. CH ₃ I)	DL-HOCH ₂ CH(C ₆ H ₅)C(CH ₃) ₂ OH (2.5 g.); DL-CH ₃ COCH(C ₂ H ₅)C ₆ H ₅	276
DL-C ₆ H ₅ CH(CH ₂ OH)CO ₂ CH ₃ (7.5 g.)	C ₆ H ₅ MgBr (40 g. C ₆ H ₅ Br)	DL-C ₆ H ₅ COCH(C ₆ H ₅)CH ₂ C ₆ H ₅ (5 g.)	276
(-)-C ₆ H ₅ CH(CH ₂ OH)CO ₂ CH ₃ (4 g.)	C ₆ H ₅ MgBr (40 g. C ₆ H ₅ Br)	DL-C ₆ H ₅ COCH(C ₆ H ₅)CH ₂ C ₆ H ₅ (2.5 g.)	276
DL-C ₆ H ₅ CH ₂ CH(OH)C ₂ H ₅ (10 g.)	C ₆ H ₅ MgBr (50 g. C ₆ H ₅ Br)	DL-C ₆ H ₅ CH ₂ CH(OH)C(C ₆ H ₅) ₂ OH (12 g.)	270
CH ₃ CH(OC ₆ H ₅)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	CH ₃ CH(OC ₆ H ₅)C(C ₆ H ₅) ₂ OH	408
4-C ₂ H ₅ OC ₆ H ₄ CO ₂ C ₂ H ₅ (100 g.)	CH ₃ MgI (30 g. Mg)	4-C ₂ H ₅ OC ₆ H ₄ C(CH ₃)=CH ₂ (35 g.); dimer (8 g.)	32

* In xylene.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₉O₃-R (cont.)			
4-CH ₃ C ₆ H ₄ CH(OH)CO ₂ C ₂ H ₅	CH ₃ MgI (4 equiv.)	4-CH ₃ C ₆ H ₄ CH(OH)C(CH ₃) ₂ OH (60-80%)	422
C₉H₉O₄-R			
2-CH ₃ OC ₆ H ₄ CH(OH)CO ₂ C ₂ H ₅	CH ₃ MgI (4 equiv.)	2-CH ₃ OC ₆ H ₄ CH(OH)C(CH ₃) ₂ OH (70-80%)	244
3-CH ₃ OC ₆ H ₄ CH(OH)CO ₂ C ₂ H ₅	CH ₃ MgI (4 equiv.)	3-CH ₃ OC ₆ H ₄ CH(OH)C(CH ₃) ₂ OH (70-80%)	244
4-CH ₃ OC ₆ H ₄ CH(OH)CO ₂ C ₂ H ₅ (42 g.)	C ₂ H ₅ MgBr (97 g. C ₂ H ₅ Br)	4-CH ₃ OC ₆ H ₄ CH(OH)C(C ₂ H ₅) ₂ OH	420
4-CH ₃ OC ₆ H ₄ CH(OH)CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr (4 equiv.)	4-CH ₃ OC ₆ H ₄ CH(OH)C(<i>n</i> -C ₃ H ₇) ₂ OH (50%)	418
2,4-(CH ₃ O) ₂ C ₆ H ₃ CO ₂ C ₂ H ₅	2,4-(CH ₃ O) ₂ C ₆ H ₃ MgI	[2,4-(CH ₃ O) ₂ C ₆ H ₃] ₃ COH (40%)	198
3,4-(CH ₃ O) ₂ C ₆ H ₃ CO ₂ C ₂ H ₅	CH ₃ MgI (2.5 equiv.)	3,4-(CH ₃ O) ₂ C ₆ H ₃ C(CH ₃) ₂ OH	33
3,4-(CH ₃ O) ₂ C ₆ H ₃ CO ₂ C ₂ H ₅	CH ₃ MgI (3-4 equiv.)	3,4-(CH ₃ O) ₂ C ₆ H ₃ C(CH ₃)=CH ₂	33
3,5-(CH ₃ O) ₂ C ₆ H ₃ CO ₂ CH ₃ (4 g.)	C ₆ H ₅ MgBr (8 g. C ₆ H ₅ Br)	3,5-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₂ COH	199
C₉H₁₀O₂N-R			
2-(CH ₃) ₂ NC ₆ H ₄ CO ₂ CH ₃ (80 g.)	C ₂ H ₅ MgBr (109 g. C ₂ H ₅ Br)	2-(CH ₃) ₂ NC ₆ H ₄ (C ₂ H ₅) ₂ COH	288
2-(CH ₃) ₂ NC ₆ H ₄ CO ₂ CH ₃ (80.0 g.)	<i>i</i> -C ₃ H ₇ MgCl (78.5 g. C ₃ H ₇ Cl)	2-(CH ₃) ₂ NC ₆ H ₄ (<i>n</i> -C ₃ H ₇) ₂ COH (65%)	288
3-(CH ₃) ₂ NC ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr (1.5 equiv.)	3-(CH ₃) ₂ NC ₆ H ₄ (C ₆ H ₅) ₂ COH	20
3-(CH ₃) ₂ NC ₆ H ₄ CO ₂ CH ₃	2-(CH ₃) ₂ NC ₆ H ₄ MgI	3-(CH ₃) ₂ NC ₆ H ₄ [2-(CH ₃) ₂ NC ₆ H ₄] ₂ COH	20
Ethyl α-cyano-α-cyclohexylideneacetate (24.0 g.)	CH ₃ MgI (19.5 g. CH ₃ I)	Ethyl α-cyano-α-(1-methylcyclohexyl)acetate (45%)	505
Ethyl α-cyano-α-cyclohexylideneacetate (15.0 g.)	<i>n</i> -C ₁₀ H ₂₁ MgBr (25.0 g. C ₁₀ H ₂₁ Br)	Ethyl α-cyano-α-(1- <i>n</i> -decylcyclohexyl)acetate (14%)	505
C₉H₁₀O₄-R₂			
Dimethyl spiro[3.3]heptane-2,6-dicarboxylate	CH ₃ MgI	α,α,α',α',-Tetramethylspiro[3.3]heptane-2,6-dimethanol	18
Dimethyl spiro[3.3]heptane-2,6-dicarboxylate (13.0 g.)	C ₆ H ₅ MgBr (0.3 mole)	α,α,α',α',-Tetraphenylspiro[3.3]heptane-2,6-dimethanol	18

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₀O₄NS-R			
4-CH ₃ C ₆ H ₄ SO ₂ HNCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	4-CH ₃ C ₆ H ₄ SO ₂ HNCH ₂ C(C ₆ H ₅) ₂ OH (50%)	45
4-CH ₃ C ₆ H ₄ SO ₂ HNCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	4-CH ₃ C ₆ H ₄ SO ₂ HNCH ₂ C(CH ₂ C ₆ H ₅) ₂ OH (35%)	45
C₉H₁₁O₂ClN-R			
C ₆ H ₅ CH ₂ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	C ₆ H ₅ CH ₂ CH(NH ₂)C(C ₂ H ₅) ₂ OH	416
C ₆ H ₅ CH ₂ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ CH(NH ₂)C(C ₆ H ₅) ₂ OH (69%)	416,273
C ₆ H ₅ CH ₂ CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	C ₆ H ₅ CH ₂ CH(NH ₂)C(CH ₂ C ₆ H ₅) ₂ OH (58%)	416
C ₆ H ₅ CH(NH ₂ ·HCl)CH ₂ CO ₂ C ₂ H ₅ (15.0 g.)	C ₆ H ₅ MgBr (98.0 g.)	C ₆ H ₅ CH(NH ₂)CH ₂ C(C ₆ H ₅) ₂ OH (1.2 g.)	273
C₉H₁₁O₃ClN-R			
C ₆ H ₅ CH(OH)CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ CH(OH)CH(NH ₂)C(C ₆ H ₅) ₂ OH (40%)	44
C ₆ H ₅ CH(OH)CH(NH ₂ ·HCl)CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	C ₆ H ₅ CH(OH)CH(NH ₂)C(CH ₂ C ₆ H ₅) ₂ OH (13%)	44
C₉H₁₄O₄-R₂			
H ₂ C[(CH ₂) ₃ CO ₂ CH ₃] ₂ (32 g., 0.15 mole)	CH ₃ MgI (46 g. CH ₃ I)	H ₂ C[(CH ₂) ₃ C(CH ₃) ₂ OH] ₂ (24 g., 75%)	185
H ₂ C[(CH ₂) ₃ CO ₂ CH ₃] ₂	C ₂ H ₅ MgX	H ₂ C[(CH ₂) ₃ C(C ₂ H ₅) ₂ OH] ₂	185
H ₂ C[(CH ₂) ₃ CO ₂ C ₂ H ₅] ₂	<i>t</i> -C ₄ H ₉ MgCl	H ₂ C[(CH ₂) ₃ C(<i>t</i> -C ₄ H ₉) ₂ OH] ₂	336
C₉H₁₅O₂-R			
(CH ₂) ₅ C(C ₂ H ₅)CO ₂ CH ₂ CH=CH ₂ (3 g.)	C ₆ H ₅ MgBr (5 ml. C ₆ H ₅ Br)	(CH ₂) ₅ C(C ₂ H ₅)C(C ₆ H ₅) ₂ OH	6
C₉H₁₇O₂-R			
<i>n</i> -C ₈ H ₁₇ CO ₂ C ₂ H ₅	C ₂ H ₅ MgX (2 equiv.)	<i>n</i> -C ₈ H ₁₇ (C ₂ H ₅) ₂ COH (80-85%); corresponding olefin (<i>ca.</i> 1%)	259

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₇O₂-R (cont.)			
L- <i>n</i> -C ₃ H ₇ (<i>n</i> -C ₄ H ₉)CHCO ₂ C ₂ H ₅	CH ₃ MgI	After dehydr'n and hydrogen'n L-CH ₃ (<i>n</i> -C ₄ H ₉)(<i>i</i> -C ₅ H ₁₁)CH	241
CH ₃ (<i>n</i> -C ₃ H ₇) ₂ CCO ₂ C ₂ H ₅ (26 g.)	<i>n</i> -C ₃ H ₇ MgBr (72 g. C ₃ H ₇ Br)	CH ₃ (<i>n</i> -C ₃ H ₇) ₂ CCH(<i>n</i> -C ₃ H ₇)OH (20 g.); recovered ester (5 g.); residue (2 g.); C ₃ H ₆ ; C ₃ H ₈	238
C₁₀H₅O₂ClN-R			
Ethyl 6-chloroquinaldate (13 g., 0.055 mole)	CH ₃ MgBr (ca. 0.18 mole)	2-(6-Chloro-2-quinolyl)-2-propanol (7.5 g., crude)	15
C₁₀H₆O₂N-R			
C ₆ H ₅ CH=C(CN)CO ₂ C ₂ H ₅	CH ₃ MgI	CH ₃ (C ₆ H ₅)CHCH(CN)CO ₂ C ₂ H ₅	220
C ₆ H ₅ CH=C(CN)CO ₂ C ₂ H ₅	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (C ₆ H ₅)CHCH(CN)CO ₂ C ₂ H ₅	220
C ₆ H ₅ CH=C(CN)CO ₂ C ₂ H ₅ (20 g.)	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH(CN)CO ₂ C ₂ H ₅ (25.4 g.)	220
C ₆ H ₅ CH=C(CN)CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ (C ₆ H ₅ CH ₂)CHCH(CN)CO ₂ C ₂ H ₅ ; CH ₃ C ₆ H ₅ ; (C ₆ H ₅ CH ₂ —) ₂	220
C ₆ H ₅ CH=C(CN)CO ₂ C ₂ H ₅	1-C ₁₀ H ₇ MgBr	C ₆ H ₅ (1-C ₁₀ H ₇)CHCH(CN)CO ₂ C ₂ H ₅	220
Ethyl quinaldate	CH ₃ MgBr (3.3 equiv.)	2-(2-Quinolyl)-2-propanol (16 g., 86%)	15
Ethyl quinaldate (46.2 g., 0.23 mole)	C ₆ H ₅ MgBr (0.50 mole)	α -(2-Quinolyl)benzhydrol (47.3 g., 66%)	97
Ethyl cinchoninate	C ₆ H ₅ MgBr	α -(4-Quinolyl)benzhdrol; 4-benzoylquinoline	355
C₁₀H₆O₄-R₂			
C ₆ H ₅ CH=C(CO ₂ C ₂ H ₅) ₂	CH ₃ MgI	CH ₃ (C ₆ H ₅)CHCH(CO ₂ C ₂ H ₅) ₂	212
C ₆ H ₅ CH=C(CO ₂ C ₂ H ₅) ₂	C ₂ H ₅ MgBr (excess)	C ₂ H ₅ (C ₆ H ₅)CHCH(CO ₂ C ₂ H ₅) ₂ (quant.)	356
C ₆ H ₅ CH=C(CO ₂ C ₂ H ₅) ₂ (25 g.)	C ₆ H ₅ MgBr (1 equiv.)	(C ₆ H ₅) ₂ CHCH(CO ₂ C ₂ H ₅) ₂ (27 g.)	212,356
C ₆ H ₅ CH=C(CO ₂ C ₂ H ₅) ₂ (32 g.)	C ₆ H ₅ MgBr (34 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ CHCH(CO ₂ C ₂ H ₅) (yielding 30 g. α -bromo deriv.)	463

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₆O₄-R₂ (<i>cont.</i>)			
C ₆ H ₅ CH=C(CO ₂ C ₂ H ₅) ₂ (6.7 g.)	C ₆ H ₅ MgBr (2 equiv.) + C ₆ H ₅ Li (excess)	1,3-Diphenyl-2-benzhydryl-1-indenol (1.5 g.)	249
C₁₀H₆O₄N-R			
Ethyl phthalimidoacetate	C ₆ H ₅ MgBr	2-C ₆ H ₅ COC ₆ H ₄ CONHCH ₂ CO ₂ C ₂ H ₅ ; 2-C ₆ H ₅ COC ₆ H ₄ CONHCH ₂ CO ₂ H; 2-C ₆ H ₅ COC ₆ H ₄ CONHCH ₂ C(C ₆ H ₅) ₂ OH	45
C₁₀H₈O₄-R₂			
[—(CH ₂) ₄ CO ₂ CH ₃] ₂	<i>n</i> -C ₃ H ₇ MgX	[—(CH ₂) ₄ C(<i>n</i> -C ₃ H ₇) ₂ OH] ₂ (<5%); non-crystallizable oil	185
C₁₀H₉O₂-R			
C ₆ H ₅ CH=C(CH ₃)CO ₂ CH ₃	CH ₃ MgI	C ₆ H ₅ CH=C(CH ₃)C(CH ₃) ₂ OH	213
C ₆ H ₅ CH=C(CH ₃)CO ₂ CH ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH(CH ₃)COC ₆ H ₅	213
C ₆ H ₅ CH=C(CH ₃)CO ₂ CH ₃ (sl. excess)	C ₆ H ₅ MgBr	C ₆ H ₅ CH=C(CH ₃)COC ₆ H ₅ ; (C ₆ H ₅) ₂ CHCH(CH ₃)COC ₆ H ₅	213
C₁₀H₉O₂N₂-R			
CH ₃ CH=C(N=NC ₆ H ₅)CO ₂ C ₂ H ₅	CH ₃ MgI	Unidentified products	438
C₁₀H₁₀O₃N-R			
CH ₃ CH(NHCOC ₆ H ₅)CO ₂ C ₂ H ₅	CH ₃ MgI (6 equiv.)	CH ₃ CH(NHCOC ₆ H ₅)C(CH ₃) ₂ OH (80%)	30
CH ₃ CH(NHCOC ₆ H ₅)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	CH ₃ CH(NHCOC ₆ H ₅)C(C ₂ H ₅) ₂ OH	417
CH ₃ CH(NHCOC ₆ H ₅)CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	CH ₃ CH(NHCOC ₆ H ₅)C(CH ₂ C ₆ H ₅) ₂ OH	45
C₁₀H₁₁O₂-R			
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ CH ₃	<i>n</i> -C ₄ H ₉ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ H (25%); CH ₃ Br (20%)	120

TABLE VIII-III (Continued)

<u>Ester</u>	<u>R MgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₁O₂-R (cont.)			
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ CH ₂ CH=CH ₂ (33.7 g.)	C ₆ H ₅ MgBr (32 g. C ₆ H ₅ Br)	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ H (95%); H ₂ C=CHCH ₂ C ₆ H ₅ (13.5 g.)	4
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ CH ₂ CH=CHCH ₃	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ CH=CHCH ₃ (75.5%)	7
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ CH ₂ CH=CHCH ₃	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ CH=CHCH ₃ (86%)	468
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ CH(CH ₃)CH=CH ₂	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ CH=CHCH ₃ (81%)	9
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ CH(CH ₃)CH=CH ₂	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ CH=CHCH ₃ (61 ± 5%); C ₆ H ₅ CH(CH ₃)CH=CH ₂ (13 ± 2%)	468
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ - <i>n</i> -C ₄ H ₉ (66.0 g.)	C ₆ H ₅ MgI (30.6 g. C ₆ H ₅ I)	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ H (61%); <i>n</i> -C ₄ H ₉ I (54%); recovered ester (14.0 g.); (C ₆ H ₅ —) ₂ "small am't"	129
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ - <i>t</i> -C ₄ H ₉	C ₆ H ₅ MgBr	C ₆ H ₅ - <i>t</i> -C ₄ H ₉ (24%)	9
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ -CH(C ₂ H ₅)CH=CH ₂	C ₆ H ₅ MgBr	After hydrogen'n, C ₆ H ₅ CH(CH ₃)- <i>n</i> -C ₄ H ₉ + C ₆ H ₅ CH(C ₂ H ₅)- <i>n</i> -C ₃ H ₇ (totaling 61%)	9
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ CH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ H (50%); C ₆ H ₅ CH ₂ Br*	120
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ CH ₂ C ₆ H ₅	C ₆ H ₅ MgBr	No cleavage in Et ₂ O	4
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ CH ₂ C ₆ H ₅	C ₆ H ₅ MgI	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ H (65%); C ₆ H ₅ CH ₂ I (70%)*	120
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -3-CH ₃	C ₆ H ₅ MgBr	3-CH ₃ C ₆ H ₄ OH (80%); 1,4-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CO] ₂ C ₆ H ₄	119
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	CH ₃ MgI	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₃ (45%); 4-CH ₃ C ₆ H ₄ OH (76%)	120
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	C ₂ H ₅ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC ₂ H ₅ (61%); 4-CH ₃ C ₆ H ₄ OH (54%)	120
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃ (20.4 g.)	C ₆ H ₅ MgBr (28.2 g.)	1,4-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CO]C ₆ H ₄ (5.0 g., 34%); 4-CH ₃ C ₆ H ₄ OH (6.4 g., 74%)	119

* Twenty-four hours reflux under N₂ in Bu₂O.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
$C_{10}H_{11}O_2 \cdot R$ (cont.)			
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	C ₆ H ₅ CH ₂ MgCl	[2,4,6-(CH ₃) ₃ C ₆ H ₂ CO —] ₂ "small am't"; 4-CH ₃ C ₆ H ₄ OH (55%)	120
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	2-CH ₃ C ₆ H ₄ MgBr	1,4-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CO] ₂ C ₆ H ₃ -2-CH ₃ (29%); 4-CH ₃ C ₆ H ₄ OH	120
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	3-CH ₃ C ₆ H ₄ MgBr	1,4-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CO] ₂ C ₆ H ₃ -2-CH ₃ (11%); 4-CH ₃ C ₆ H ₄ OH	119
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	4-CH ₃ C ₆ H ₄ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₃ COC ₆ H ₄ -2-(C ₆ H ₄ -4-CH ₃) (13%); 4-CH ₃ C ₆ H ₄ OH (95%)	120
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	2-CH ₃ OC ₆ H ₄ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC ₆ H ₄ -2-(C ₆ H ₄ -2-OCH ₃) (13%); 4-CH ₃ C ₆ H ₄ OH (74%)	120
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	3-CH ₃ OC ₆ H ₄ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ C ₆ H ₄ -2-(C ₆ H ₄ -3-OCH ₃) (6%); 4-CH ₃ C ₆ H ₄ OH (75%)*	120
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	3-CH ₃ OC ₆ H ₄ MgBr	1,4-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CO] ₂ C ₆ H ₃ -2-(C ₆ H ₄ -3-OCH ₃) (3.5%); 4-CH ₃ C ₆ H ₄ OH†	119
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ CO (3%); [2,4,6-(CH ₃) ₃ C ₆ H ₂ CO —] ₂ (trace); 4-CH ₃ C ₆ H ₄ OH (85%)	120
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	1-C ₁₀ H ₇ MgBr	1-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CO]C ₁₀ H ₆ -2-α-C ₁₀ H ₇ (trace); 4-CH ₃ C ₆ H ₄ OH	120
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ CH(C ₆ H ₅)CH ₂ C ₆ H ₅ (5.0 g., 0.020 mole)	CH ₃ MgI (0.045 mole)	<i>trans</i> -(C ₆ H ₅ CH =) ₂ (1.0 g., 30%); [C ₆ H ₅ CH ₂ (C ₆ H ₅)CH —] ₂ (0.3 g., 9%)	153
2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ CH(C ₆ H ₅)CH ₂ C ₆ H ₅ (6.8 g., 0.028 mole)	C ₂ H ₅ MgBr (0.040 mole)	Mixture of <i>cis</i> - and <i>trans</i> -(C ₆ H ₅ CH =) ₂ (1.5 g., 45%); [C ₆ H ₅ CH ₂ (C ₆ H ₅)CH —] ₂ (0.3 g., 8%); 2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ H (76%)	153

* Addition of Bu₂O-ester solution to stirred Bu₂O-Grignard reagent solution; five hours at 115° under N₂.

† Addition of Bu₂O-ester solution to stirred Bu₂O-Grignard reagent solution; two hours at 100° under N₂.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₁O₂-R (cont.)			
2,4,6- (CH ₃) ₃ C ₆ H ₂ CO ₂ CH(C ₆ H ₅)CH ₂ C ₆ H ₅ (13.0 g., 0.05 mole)	C ₆ H ₅ MgBr (0.10 mole)	<i>trans</i> -(C ₆ H ₅ CH=) ₂ (5.5 g., 68%); <i>cis</i> - (C ₆ H ₅ CH=) ₂ (1.1 g., 13%); 2,4,6- (CH ₃) ₃ C ₆ H ₂ CO ₂ H (7.3 g., 90%)	153
C₁₀H₁₁O₃-R			
4-C ₂ H ₅ OC ₆ H ₄ CH ₂ CO ₂ C ₂ H ₅	4-CH ₃ OC ₆ H ₄ MgBr	4-C ₂ H ₅ OC ₆ H ₄ CH ₂ (4-CH ₃ OC ₆ H ₄) ₂ COH	164
4-C ₂ H ₅ OC ₆ H ₄ CH ₂ CO ₂ C ₂ H ₅ (10.4 parts)	4-C ₂ H ₅ OC ₆ H ₄ MgBr (30.0 parts C ₈ H ₉ BrO)	4-C ₂ H ₅ OC ₆ H ₄ CH ₂ (4-C ₂ H ₅ OC ₆ H ₄) ₂ COH	164
4-C ₂ H ₅ OC ₆ H ₄ CH ₂ CO ₂ C ₂ H ₅ (10.0 g.)	4- <i>n</i> -C ₃ H ₇ OC ₆ H ₄ MgBr (32.3 g. C ₉ H ₁₁ BrO)	4-C ₂ H ₅ OC ₆ H ₄ CH ₂ (4- <i>n</i> -C ₃ H ₇ OC ₆ H ₄) ₂ COH	164
HO(CH ₃)(C ₆ H ₅ CH ₂)CCO ₂ C ₂ H ₅ (25 g.)	C ₆ H ₅ MgBr (75 g. C ₆ H ₅ Br)	HO(CH ₃)(C ₆ H ₅ CH ₂)CC(C ₆ H ₅) ₂ OH (27 g., <i>ca.</i> 57%, crude)	420
C₁₀H₁₂O₃N-R			
Ethyl cryptopyrrylglyoxalate* (2.00 g.)	Cryptopyrryl-MgBr† (10.00 g. cryptopyrrole)	(5-Cryptopyrryl-CO—) ₂ (1.35 g., 50%)	107
C₁₀H₁₂O₄NS-R			
4-CH ₃ C ₆ H ₄ SO ₂ NHCH(CH ₃)CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	4-CH ₃ C ₆ H ₄ SO ₂ NHCH(CH ₃)C(CH ₂ C ₆ H ₅) ₂ OH (39%)	45
C₁₀H₁₂O₅-R₂			
Diethyl 2-oxo-1,3- cyclohexanediacetate (12.0 g.)	C ₆ H ₅ MgBr (7.5 g. C ₆ H ₅ Br)	Diethyl 2-hydroxy-2-phenyl-1,3- cyclohexanediacetate	78

* Ethyl (3,5-dimethyl-4-ethyl-2-pyrrol)glyoxalate.

† From 2,4-dimethyl-3-ethylpyrrole.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₅O₃-R			
Methyl 2,2,3-trimethyl-3-formylcyclopentanecarboxylate	CH ₃ MgI (4 equiv.)	2,2,3-Trimethyl-3- α -hydroxyethylcyclopentanecarboxylic acid δ -lactone* (62%)†	440
Methyl 2,2,3-trimethyl-3-formylcyclopentanecarboxylate (43 g.)	CH ₃ MgI (125 g. CH ₃ I)	α ,1,2,2-Tetramethyl-3-isopropenylcyclopentanemethanol; 1,2,4,4,8,8-hexamethyl-3-oxabicyclo[3.2.1]octane; 1,2,2-trimethyl-1-vinyl-3-isopropenylcyclopentane‡	441
Methyl 2,2,3-trimethyl-3-formylcyclopentanecarboxylate (50 g.)	C ₂ H ₅ MgBr (110 g. C ₂ H ₅ Br)	2,2,3-Trimethyl-3- α -hydroxypropylcyclopentanecarboxylic acid δ -lactone (40%); 2,2,3-trimethyl-3-hydroxymethylcyclopentanecarboxylic acid δ -lactone (4%)†	440
Methyl 2,2,3-trimethyl-3-formylcyclopentanecarboxylate (40 g.)	C ₂ H ₅ MgBr (109 g. C ₂ H ₅ Br)	α , α' , α' -Triethyl-1,2,2-trimethylcyclopentane-1,3-dimethanol; α -ethyl-1,2,2-trimethyl-3-(3- Δ^2 -pentenyl)cyclopentanemethanol; 1,8,8-trimethyl-2,4,4-triethyl-3-oxabicyclo[3.2.1]octane; 1,2,2-trimethyl-1-propenyl-3-(3- Δ^2 -pentenyl)cyclopentane §	441
Methyl 2,2,3-trimethyl-3-formylcyclopentanecarboxylate (30 g.)	C ₂ H ₅ MgBr (82 g. C ₂ H ₅ Br)	α -Ethyl-1,2,2-trimethyl-3-(3- Δ^2 -pentenyl)cyclopentanemethanol; 1,8,8-trimethyl-2,4,4-triethyl-3-oxabicyclo[3.2.1]octane; 1,2,2-trimethyl-1-propenyl-3-(3- Δ^2 -pentenyl)cyclopentane‡	441

* 4,5,8,8-Tetramethyl-3-oxabicyclo[3.2.1]octan-2-one.

† Dropwise addition of Et₂O-ester solution to agitated Grignard reagent solution; one hour reflux; twenty-four hours at room temperature.

‡ Gradual addition of xylene-ester solution to Grignard reagent solution; distillation of Et₂O; four hours reflux.

§ Slow addition of toluene-ester solution to Grignard reagent solution; distillation of Et₂O; two hours reflux.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₅O₃-R (cont.)			
Methyl 2,2,3-trimethyl-3-formylcyclopentanecarboxylate	<i>n</i> -C ₃ H ₇ MgBr	2,2,3-Trimethyl-3- α -hydroxybutylcyclopentane-carboxylic acid δ -lactone; 2,2,3-trimethyl-3-hydroxymethylcyclopentanecarboxylic acid δ -lactone	440
Methyl 2,2,3-trimethyl-3-formylcyclopentanecarboxylate	<i>n</i> -C ₄ H ₉ MgBr	2,2,3-Trimethyl-3- α -hydroxyamylcyclopentane-carboxylic acid δ -lactone; 2,2,3-trimethyl-3-hydroxymethylcyclopentanecarboxylic acid δ -lactone	440
Methyl 2,2,3-trimethyl-3-formylcyclopentanecarboxylate	C ₆ H ₅ MgBr (2 equiv.)	2,2,3-Trimethyl-3- α -hydroxybenzylcyclopentane-carboxylic acid δ -lactone; (C ₆ H ₅ —) ₂	440
Methyl 2,2,3-trimethyl-3-formylcyclopentanecarboxylate	C ₆ H ₅ CH ₂ MgCl	2,2,3-Trimethyl-3- α -hydroxyphenethylcyclopentanecarboxylic acid δ -lactone; unidentified oils	440
C₁₀H₁₆O₄-R₂			
[—(CH ₂) ₄ CO ₂ CH ₃] ₂	C ₆ H ₅ MgBr	[—(CH ₂) ₄ C(C ₆ H ₅) ₂ OH] ₂ (ca. 80%)	377
[—(CH ₂) ₄ CO ₂ C ₂ H ₅] ₂ (130 g.)	CH ₃ MgBr (100 g. Mg)	[—(CH ₂) ₄ C(CH ₃) ₂ OH] ₂ (70 g.)	228
[—(CH ₂) ₄ CO ₂ C ₂ H ₅] ₂ (70 g.)	CH ₃ MgI (230 g. CH ₃ I)	[—(CH ₂) ₄ C(CH ₃) ₂ OH] ₂ (92%)	337
[—(CH ₂) ₄ CO ₂ C ₂ H ₅] ₂	C ₂ H ₅ MgBr	[—(CH ₂) ₄ C(C ₂ H ₅) ₂ OH] ₂ (70%)	337,227
[—(CH ₂) ₄ CO ₂ C ₂ H ₅] ₂ (50 g.)	<i>n</i> -C ₄ H ₉ MgBr (115 g. C ₄ H ₉ Br)	[—(CH ₂) ₄ C(<i>n</i> -C ₄ H ₉) ₂ OH] ₂ (68%)	337
[—(CH ₂) ₄ CO ₂ C ₂ H ₅] ₂	<i>t</i> -C ₄ H ₉ MgCl (4 equiv.)	[—(CH ₂) ₄ CO ₂ H] ₂ ; a hydroxy acid, m. 121°	336
[—(CH ₂) ₄ CO ₂ C ₂ H ₅] ₂ (0.2 mole)	<i>t</i> -C ₄ H ₉ MgCl (2.5 mole)	[—(CH ₂) ₄ C(<i>t</i> -C ₄ H ₉) ₂ OH] ₂ ; <i>i</i> -C ₄ H ₈ ; a sat'd hydrocarbon; liquid byproducts	336
[—(CH ₂) ₄ CO ₂ C ₂ H ₅] ₂ (34 g.)	<i>n</i> -C ₆ H ₁₃ MgBr (120 g. C ₆ H ₁₃ Br)	[—(CH ₂) ₄ C(<i>n</i> -C ₆ H ₁₃) ₂ OH] ₂	337

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₇O₂-R			
Ethyl campholate*	<i>n</i> -C ₃ H ₇ MgX†	α -Propyl-1,2,2,3-tetramethylcyclopentane-methanol; C ₃ H ₆ ; C ₃ H ₈	238
C₁₀H₁₉O₂-R			
<i>n</i> -C ₉ H ₁₉ CO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₉ H ₁₉ (<i>n</i> -C ₄ H ₉) ₂ COH	334
L-CH ₃ (<i>n</i> -C ₇ H ₁₅)CHCO ₂ C ₂ H ₅	CH ₃ MgI	After dehydr'n and hydrogen'n, L-CH ₃ (<i>i</i> -C ₃ H ₇)(<i>n</i> -C ₇ H ₁₅)CH	242
L- <i>n</i> -C ₃ H ₇ (<i>n</i> -C ₅ H ₁₁)CHCO ₂ C ₂ H ₅	CH ₃ MgI	After dehydr'n and hydrogen'n, L- <i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇)(<i>n</i> -C ₅ H ₁₁)CH	241
C₁₁H₇O₂-R			
1-C ₁₀ H ₇ CO ₂ C ₂ H ₅	CH ₃ MgI (2 equiv.)	1-C ₁₀ H ₇ (CH ₃) ₂ COH	88
C₁₁H₇O₃-R			
5-HOC ₁₀ H ₆ -1-CO ₂ CH ₃ (4 g.)	C ₆ H ₅ MgBr (14 ml. C ₆ H ₅ Br)	5-HOC ₁₀ H ₆ -1-C(C ₆ H ₅) ₂ OH (63%)	499
6-HOC ₁₀ H ₆ -1-CO ₂ CH ₃	C ₆ H ₅ MgBr (excess)	6-HOC ₁₀ H ₆ -1-C(C ₆ H ₅) ₂ OH	499
7-HOC ₁₀ H ₆ -1-CO ₂ CH ₃	C ₆ H ₅ MgBr	7-HOC ₁₀ H ₆ -1-C(C ₆ H ₅) ₂ OH (67%)	499
1-HOC ₁₀ H ₆ -2-CO ₂ CH ₃	CH ₃ MgI	1-HOC ₁₀ H ₆ -2-C(CH ₃)=CH ₂ (60%)	343
1-HOC ₁₀ H ₆ -2-CO ₂ CH ₃	C ₂ H ₅ MgI	1-HOC ₁₀ H ₆ -2-C(C ₂ H ₅) ₂ OH (<i>ca.</i> 60%)	343
1-HOC ₁₀ H ₆ -2-CO ₂ CH ₃ (6 g.)	C ₆ H ₅ MgBr (20 g. C ₆ H ₅ Br)	1-HOC ₁₀ H ₆ -2-C(C ₆ H ₅) ₂ OH (7 g.)	197
1-HOC ₁₀ H ₆ -2-CO ₂ CH ₃	C ₆ H ₅ MgBr	1-HOC ₁₀ H ₆ -2-C(C ₆ H ₅) ₂ OH (10%); 2-benzhydrilidene-1(2 <i>H</i>)-naphthalenone	343
1-HOC ₁₀ H ₆ -2-CO ₂ CH ₃	1-C ₁₀ H ₇ MgBr	2-(Di- α -naphthylmethylene)-1(2 <i>H</i>)-naphthalenone	343
3-HOC ₁₀ H ₆ -2-CO ₂ CH ₃ (5 g.)	CH ₃ MgI (18 g. CH ₃ I)	3-HOC ₁₀ H ₆ -2-C(CH ₃) ₂ OH (60-70%)	225
3-HOC ₁₀ H ₆ -2-CO ₂ CH ₃ (5 g.)	C ₆ H ₅ MgBr (20 g. C ₆ H ₅ Br)	3-HOC ₁₀ H ₆ -2-C(C ₆ H ₅) ₂ OH (70-80%)	225

* Ethyl 1,2,2,3-tetramethylcyclopentanecarboxylate.

† X = Cl, Br.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₇O₃-R (cont.)			
3-HOC ₁₀ H ₆ -2-CO ₂ CH ₃ (5 g.)	C ₆ H ₅ CH ₂ MgCl (18 g. C ₇ H ₇ Cl)	3-HOC ₁₀ H ₆ -2-C(CH ₂ C ₆ H ₅) ₂ OH (70%)	225
3-HOC ₁₀ H ₆ -2-CO ₂ CH ₃ (10 g.)	1-C ₁₀ H ₇ MgBr (55 g. C ₁₀ H ₇ Br)	3-HOC ₁₀ H ₆ -2-C(1-C ₁₀ H ₇) ₂ OH (30-70%)	225
3-HOC ₁₀ H ₆ -2-CO ₂ C ₂ H ₅ (6.5 g.)	C ₆ H ₅ MgBr (30.0 g. C ₆ H ₅ Br)	3-HOC ₁₀ H ₆ -2-C(C ₆ H ₅) ₂ OH (8.0 g.)	197
6-HOC ₁₀ H ₆ -2-CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	6-HOC ₁₀ H ₆ -2-C(C ₆ H ₅) ₂ OH	499
8-HOC ₁₀ H ₆ -2-CO ₂ CH ₃ (1.85 g.)	C ₆ H ₅ MgBr (6.6 ml. C ₆ H ₅ Br)	8-HOC ₁₀ H ₆ -2-C(C ₆ H ₅) ₂ OH (67%)	499
C₁₁H₉O₂-R			
C ₆ H ₅ (CH=CH) ₂ CO ₂ CH ₃ (stable form)	C ₂ H ₅ MgBr (4 equiv.)	C ₆ H ₅ (CH=CH) ₂ C(C ₂ H ₅) ₂ OH; unidentified products	357
C ₆ H ₅ (CH=CH) ₂ CO ₂ CH ₃ (stable form) (28.0 g.)	C ₆ H ₅ MgBr (2.5 equiv.)	C ₆ H ₅ CH=CHCH(C ₆ H ₅)CH ₂ COC ₆ H ₅ (25.5 g.); recovered ester (9.0 g.)	357
C ₆ H ₅ (CH=CH) ₂ CO ₂ CH ₃ (allo form)	C ₆ H ₅ MgBr (4 equiv.)	C ₆ H ₅ CH=CHCH(C ₆ H ₅)CH ₂ COC ₆ H ₅ (60%)	357
C ₆ H ₅ (CH=CH) ₂ CO ₂ CH ₃ (stable form (14.0 g.)	C ₆ H ₅ CH ₂ MgBr	C ₆ H ₅ (CH=CH) ₂ C(CH ₂ C ₆ H ₅) ₂ OH (2.0 g., crude); C ₆ H ₅ CH=CHCH(CH ₂ C ₆ H ₅)CH ₂ COCH ₂ C ₆ H ₅ (12.5 g.); C ₆ H ₅ CH=CHCH(CH ₂ C ₆ H ₅)CH ₂ CO ₂ CH ₃ (1.2 g. as acid)	357
C₁₁H₁₃O₃-R			
4- <i>n</i> -C ₃ H ₇ OC ₆ H ₄ CH ₂ CO ₂ C ₂ H ₅ (6.7 parts)	C ₆ H ₅ MgBr (14.1 parts C ₆ H ₅ Br)	4- <i>n</i> -C ₃ H ₇ OC ₆ H ₄ CH ₂ (C ₆ H ₅) ₂ COH	164
C₁₁H₁₃O₄-R			
4-CH ₃ OC ₆ H ₄ CH(OC ₂ H ₅)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	4-CH ₃ OC ₆ H ₄ CH(OC ₂ H ₅)C(C ₂ H ₅) ₂ OH (yielding 60-70% 4-anisyl-3-hexanone)	367
C₁₂H₅O₂N-R			
C ₆ H ₅ CH=CHCH=C(CN)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr (2.5 equiv.)	C ₆ H ₅ CH=CHCH(C ₂ H ₅)CH(CN)CO ₂ C ₂ H ₅ (quant.)	250

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₈O₂N-R (cont.)			
C ₆ H ₅ CH=CHCH=C(CN)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ CH=CHCH(C ₆ H ₅)CH(CN)CO ₂ C ₂ H ₅ (quant.)	250
C₁₂H₈O₄-R₂			
C ₆ H ₅ CH=CHCH=C(CO ₂ CH ₃) ₂	CH ₃ MgI	C ₆ H ₅ CH=CHCH(CH ₃)CH(CO ₂ CH ₃) ₂ (76%)	352
C ₆ H ₅ CH=CHCH=C(CO ₂ CH ₃) ₂ (16 g.)	C ₆ H ₅ MgBr	C ₆ H ₅ CH=CHCH(C ₆ H ₅)CH(CO ₂ CH ₃) ₂ (21 g.)	352
C ₆ H ₅ CH=CHCH=C(CO ₂ CH ₃) ₂	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH=CHCH(CH ₂ C ₆ H ₅)CH(CO ₂ CH ₃) ₂	352
C₁₂H₈O₂-R			
4-CH ₃ C ₁₀ H ₆ -2-CO ₂ CH ₃	CH ₃ MgBr	4-CH ₃ C ₁₀ H ₆ -2-C(CH ₃) ₂ OH	93
C₁₂H₁₀O₄NS-R			
C ₁₀ H ₇ SO ₂ NHCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₁₀ H ₇ SO ₂ NHCH ₂ C(C ₆ H ₅) ₂ OH (43%)	45
C₁₂H₁₁O₂-R			
Ethyl 4-methyl-1-naphthoate	CH ₃ MgI	2-(4-Methyl-1-naphthyl)-2-propanol	24
C₁₂H₁₃O₂-R			
Methyl 4-methyl-1,2,3,4-tetrahydro-2-naphthoate	CH ₃ MgBr	2-(4-Methyl-1,2,3,4-tetrahydro-2-naphthyl)-2-propanol	93
C₁₂H₁₃O₅-R			
C ₆ H ₅ CO(CH ₃) ₂ CCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₁₈ H ₃₈ O ₂ , m. 146-147°; β,β-di-methyl-γ,γ-diphenyl-γ-butyrolactone (?)	523
C₁₂H₁₃O₄N₂-R			
C ₆ H ₅ COHNCH ₂ COHNCH(CH ₃)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ COHNCH ₂ COHNCH(CH ₃)C(C ₆ H ₅) ₂ OH (61%)	45

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₁₃O₄N₂-R (<i>cont.</i>)			
C ₆ H ₅ COHNCH ₂ COHNCH(CH ₃)CO ₂ -C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	C ₆ H ₅ COHNCH ₂ COHNCH(CH ₃)C(CH ₂ C ₆ H ₅) ₂ OH	45
C₁₂H₁₅O₂-R			
CH ₃ (C ₂ H ₅)(C ₆ H ₅ CH ₂)CCO ₂ CH ₂ CH=CH ₂ (20 g.)	C ₆ H ₅ MgBr (21 ml. C ₆ H ₅ Br)	CH ₃ (C ₂ H ₅)(C ₆ H ₅ CH ₂)CCO ₂ H (14.5 g., 87%); C ₆ H ₅ CH ₂ CH=CH ₂ (7.0 g., 70%)	6
C₁₂H₂₃O₂-R			
<i>n</i> -C ₁₁ H ₂₃ CO ₂ CH ₃	C ₆ H ₅ MgBr	<i>n</i> -C ₁₁ H ₂₃ (C ₆ H ₅) ₂ COH (yielding 80–90% alkene)	377
<i>n</i> -C ₁₁ H ₂₃ CO ₂ CH ₃	<i>n</i> -C ₁₀ H ₂₁ MgBr (2.5 equiv.)	<i>n</i> -C ₁₁ H ₂₃ (<i>n</i> -C ₁₀ H ₂₁) ₂ COH	460
<i>n</i> -C ₁₁ H ₂₃ CO ₂ C ₂ H ₅	<i>n</i> -C ₄ H ₉ MgCl	<i>n</i> -C ₁₁ H ₂₃ (<i>n</i> -C ₄ H ₉) ₂ COH (65%)	326
<i>n</i> -C ₁₁ H ₂₃ CO ₂ C ₂ H ₅	<i>s</i> -C ₄ H ₉ MgBr	(<i>n</i> -C ₁₁ H ₂₃) ₂ CO	327
<i>n</i> -C ₁₁ H ₂₃ CO ₂ C ₂ H ₅	<i>t</i> -C ₄ H ₉ MgCl	(<i>n</i> -C ₁₁ H ₂₃) ₂ CO (30–35%)	326, 327
<i>n</i> -C ₁₁ H ₂₃ CO ₂ - <i>s</i> -C ₈ H ₁₇	<i>t</i> -C ₄ H ₉ MgCl	(<i>n</i> -C ₁₁ H ₂₃) ₂ CO; <i>n</i> -C ₁₁ H ₂₃ CO ₂ H	338
(CH ₃)(<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCO ₂ CH ₃	CH ₃ MgBr	CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCO ₂ H (13.0%); recovered ester (70.3%)	454
C₁₃H₉O₂-R			
2-C ₆ H ₅ C ₆ H ₄ CO ₂ C ₂ H ₅	3-C ₆ H ₅ C ₆ H ₄ MgBr	2-C ₆ H ₅ C ₆ H ₄ (3-C ₆ H ₅ C ₆ H ₄) ₂ COH	81
4-C ₆ H ₅ C ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr	4-C ₆ H ₅ C ₆ H ₄ (C ₆ H ₅) ₂ COH (<i>ca.</i> quant.)	372
4-C ₆ H ₅ C ₆ H ₄ CO ₂ CH ₃	4-C ₆ H ₅ C ₆ H ₄ MgI	(4-C ₆ H ₅ C ₆ H ₄) ₃ COH (yield depends on quality of I ₂ -activated Mg)	372
C₁₃H₉O₃-R			
Ethyl α -phenyl- β -2-furylacrylate (30 g.)	C ₂ H ₅ MgBr (42 g. C ₂ H ₅ Br)	C ₂ H ₅ (α -C ₄ H ₃ O)CHCH(C ₆ H ₅)CO ₂ C ₂ H ₅ (30 g.)	265

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₉O₃-R (cont.)			
Ethyl α -phenyl- β -2-furylacrylate (30 g.)	C ₆ H ₅ MgBr (49 g. C ₆ H ₅ Br)	C ₆ H ₅ (α -C ₄ H ₃ O)CHCH(C ₆ H ₅)CO ₂ C ₂ H ₅ (20 g.); α -C ₄ H ₃ OCH=C(C ₆ H ₅)C(C ₆ H ₅) ₂ OH	265
Propyl α -phenyl- β -2-furylacrylate (30 g.)	C ₂ H ₅ MgBr (32 g. C ₂ H ₅ Br)	C ₂ H ₅ (α -C ₄ H ₃ O)CHCH(C ₆ H ₅)CO ₂ - <i>n</i> -C ₃ H ₇ (29 g.)	265
Propyl α -phenyl- β -2-furylacrylate (30 g.)	C ₆ H ₅ MgBr (46 g. C ₆ H ₅ Br)	C ₆ H ₅ (α -C ₄ H ₃ O)CHCH(C ₆ H ₅)CO ₂ - <i>n</i> -C ₃ H ₇ (19 g.); α -C ₄ H ₃ OCH=C(C ₆ H ₅)C(C ₆ H ₅) ₂ OH (17 g.)	265
Butyl α -phenyl- β -2-furylacrylate (20 g.)	C ₂ H ₅ MgBr (19 g. C ₂ H ₅ Br)	C ₂ H ₅ (α -C ₄ H ₃ O)CHCH(C ₆ H ₅)CO ₂ - <i>n</i> -C ₄ H ₉ (19 g.)	265
Butyl α -phenyl- β -2-furylacrylate (30 g.)	C ₆ H ₅ MgBr (50 g. C ₆ H ₅ Br)	C ₆ H ₅ (α -C ₄ H ₃ O)CHCH(C ₆ H ₅)CO ₂ - <i>n</i> -C ₄ H ₉ (19 g.); α -C ₄ H ₃ OCH=C(C ₆ H ₅)C(C ₆ H ₅) ₂ OH (16 g.)	265
Amyl α -phenyl- β -2-furylacrylate (20 g.)	C ₂ H ₅ MgBr (26 g. C ₂ H ₅ Br)	C ₂ H ₅ (α -C ₄ H ₃ O)CHCH(C ₆ H ₅)CO ₂ - <i>n</i> -C ₆ H ₁₁ (19 g.)	265
Amyl α -phenyl- β -2-furylacrylate (30 g.)	C ₆ H ₅ MgBr (47 g. C ₆ H ₅ Br)	C ₆ H ₅ (α -C ₄ H ₃ O)CHCH(C ₆ H ₅)CO ₂ - <i>n</i> -C ₅ H ₁₁ (17 g.); α -C ₄ H ₃ OCH=C(C ₆ H ₅)C(C ₆ H ₅) ₂ OH (12 g.)	265
C₁₃H₁₀O₂N-R			
2-C ₆ H ₅ NHC ₆ H ₄ CO ₂ CH ₃ (30.0 g., 0.132 mole)	CH ₃ MgI (82.5 g., 0.6 mole CH ₃ I)	2-C ₆ H ₅ NHC ₆ H ₄ - <i>t</i> -C ₄ H ₉ (10.0 g., 33%); 9,9-dimethylacridan	506,500
2-C ₆ H ₅ NHC ₆ H ₄ CO ₂ CH ₃ (30.0 g., 0.132 mole)	C ₂ H ₅ MgI (0.3 mole)	9,9-Diethylacridan (27.0 g., 79%)	500
2-C ₆ H ₅ NHC ₆ H ₄ CO ₂ CH ₃ (16.0 g.)	C ₆ H ₅ MgBr (51.0 g. C ₆ H ₅ Br)	9,9-Diphenylacridan	507
C₁₃H₁₁O₂-R			
2,3-(CH ₃) ₂ C ₁₀ H ₅ -1-CO ₂ CH ₂ CH=CH ₂ (15.1 g.)	C ₆ H ₅ MgBr (13.0 ml. C ₆ H ₅ Br)	2,3-(CH ₃) ₂ C ₁₀ H ₅ -1-CO ₂ H (12.2 g., 97.0%); C ₆ H ₅ CH ₂ CH=CH ₂ (6.0 g., 82.4%)	6
4,7-(CH ₃) ₂ C ₁₀ H ₅ -1-CO ₂ CH ₃	CH ₃ MgI	4,7-(CH ₃) ₂ C ₁₀ H ₅ -1-C(CH ₃) ₂ OH	24

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₁₁O₂N₂-R			
2- <i>p</i> -H ₂ NC ₆ H ₄ NHC ₆ H ₄ CO ₂ CH ₃ (0.5 g.)	CH ₃ MgI (3.9 g. CH ₃ I)	2- <i>p</i> -H ₂ NC ₆ H ₄ NHC ₆ H ₄ C(CH ₃) ₂ OH	511
2- <i>p</i> -H ₂ NC ₆ H ₄ NHC ₆ H ₄ CO ₂ CH ₃ (0.5 g.)	C ₂ H ₅ MgBr (2.9 g. C ₂ H ₅ Br)	2- <i>p</i> -H ₂ NC ₆ H ₄ NHC ₆ H ₄ C(C ₂ H ₅) ₂ OH	512
C₁₃H₁₁O₃N₂-R			
2- <i>p</i> -HOC ₆ H ₄ NH-5-H ₂ NC ₆ H ₃ CO ₂ CH ₃ (0.2 g.)	C ₆ H ₅ MgBr (3.0 g. C ₆ H ₅ Br)	2- <i>p</i> -HOC ₆ H ₄ NH-5-H ₂ NC ₆ H ₃ C(C ₆ H ₅) ₂ OH	510
C₁₃H₁₂O₂N₃-R			
2- <i>p</i> -H ₂ NC ₆ H ₄ NH-5-H ₂ NC ₆ H ₃ CO ₂ CH ₃ (0.5 g.)	CH ₃ MgI (3.9 g. CH ₃ I)	2- <i>p</i> -H ₂ NC ₆ H ₄ NH-5-H ₂ NC ₆ H ₃ C(CH ₃) ₂ OH	511,5
2- <i>p</i> -H ₂ NC ₆ H ₄ NH-5-H ₂ NC ₆ H ₃ CO ₂ CH ₃ (0.5 g.)	C ₂ H ₅ MgBr (2.9 g. C ₂ H ₅ Br)	2- <i>p</i> -H ₂ NC ₆ H ₄ NH-5-H ₂ NC ₆ H ₃ C(C ₂ H ₅) ₂ OH (yielding 60% of the carbazine dihydrochloride)	512
2- <i>m</i> -H ₂ NC ₆ H ₄ NH-5-C ₆ H ₃ CO ₂ CH ₃ (1.0 g.)	C ₆ H ₅ MgBr (7.5 g. C ₆ H ₅ Br)	2- <i>m</i> -H ₂ NC ₆ H ₄ NH-5-H ₂ NC ₆ H ₃ C(C ₆ H ₅) ₂ OH	509
2-C ₆ H ₅ NH-3,5-(H ₂ N) ₂ C ₆ H ₂ CO ₂ CH ₃ (0.2 g.)	C ₆ H ₅ MgBr (1.2 g. C ₆ H ₅ Br)	2-C ₆ H ₅ NH-3,5-(H ₂ N) ₂ C ₆ H ₂ C(C ₆ H ₅) ₂ OH	508
C₁₃H₁₂O₃N₃-R			
2- <i>p</i> -HOC ₆ H ₄ NH-3,5- (H ₂ N) ₂ C ₆ H ₂ CO ₂ CH ₃ (3.8 g.)	C ₆ H ₅ MgBr (45.0 g. C ₆ H ₅ Br)	2- <i>p</i> -HOC ₆ H ₄ NH-3,5-(H ₂ N) ₂ C ₆ H ₂ C(C ₆ H ₅) ₂ OH	510
C₁₃H₁₃O₂N₄-R			
2- <i>p</i> -H ₂ NC ₆ H ₄ NH-3,5- (H ₂ N) ₂ C ₆ H ₂ CO ₂ CH ₃	C ₆ H ₅ MgBr	2- <i>p</i> -H ₂ NC ₆ H ₄ NH-3,5-(H ₂ N) ₂ C ₆ H ₂ C(C ₆ H ₅) ₂ OH	510
C₁₃H₁₅O₂-R			
4-(CH ₂) ₅ CHC ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr (2 equiv.)	4-(CH ₂) ₅ CHC ₆ H ₄ (C ₆ H ₅) ₂ COH	477

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₁₅O₂-R (<i>cont.</i>)			
4-(CH ₂) ₅ CHC ₆ H ₄ CO ₂ CH ₃ (13 g.)	4-(CH ₂) ₅ CHC ₆ H ₄ MgI (57 g. C ₁₂ H ₁₅ I)	[4-(CH ₂) ₅ CHC ₆ H ₄] ₂ CO; [4-(CH ₂) ₅ CHC ₆ H ₄] ₃ COH	304
C₁₃H₁₆O₃N-R			
<i>i</i> -C ₄ H ₉ CH(NHCOC ₆ H ₅)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	<i>i</i> -C ₄ H ₉ CH(NHCOC ₆ H ₅)C(C ₆ H ₅) ₂ OH (52%)	45
C₁₃H₁₇O₂-R			
2,4,6-(C ₂ H ₅) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	C ₆ H ₅ MgBr	1,4-[2,4,6-(C ₂ H ₅) ₃ C ₆ H ₂ CO] ₂ C ₆ H ₄ ; 4-CH ₃ C ₆ H ₄ OH	119
C₁₃H₁₇O₄-R			
<i>n</i> -C ₄ H ₉ O(4-CH ₃ OC ₆ H ₄)CHCO ₂ - <i>n</i> -C ₄ H ₉	C ₂ H ₅ MgCl	<i>n</i> -C ₄ H ₉ O(4-CH ₃ OC ₆ H ₄)CHC(C ₂ H ₅) ₂ OH (yielding 4-anisyl-3-hexanone) 75%	363
<i>n</i> -C ₄ H ₉ O(4-CH ₃ OC ₆ H ₄)CHCO ₂ - <i>n</i> -C ₄ H ₉ (1030 g.)	C ₂ H ₅ MgBr (908 g. C ₂ H ₅ Br)	<i>n</i> -C ₄ H ₉ O(4-CH ₃ OC ₆ H ₄)CHC(C ₂ H ₅) ₂ OH (yielding 60-70% 4-anisyl-3-hexanone)	367
C₁₄H₆O₄-R₂			
(—C ₆ H ₄ -2-CO ₂ CH ₃) ₂	C ₆ H ₅ MgBr	5,5,7,7-Tetraphenyl-5,7-dihydrodibenz[<i>c,e</i>]oxepin	370
(—C ₆ H ₄ -3-CO ₂ CH ₃) ₂ (5 g.)	C ₆ H ₅ MgBr (18 g. C ₆ H ₅ Br)	[—C ₆ H ₄ -3-C(C ₆ H ₅) ₂ OH] ₂ (8 g.)	370
(—C ₆ H ₄ -4-CO ₂ CH ₃) ₂	C ₆ H ₅ MgBr (2 equiv.)	[—C ₆ H ₄ -4-C(C ₆ H ₅) ₂ OH] ₂	432
(—C ₆ H ₄ -4-CO ₂ CH ₃) ₂ (5 g.)	4-C ₆ H ₅ C ₆ H ₄ MgI (30 g. C ₁₂ H ₉ I)	[—C ₆ H ₄ -4-C(C ₆ H ₄ -4-C ₆ H ₅) ₂ OH] ₂	370
C₁₄H₉O₃-R			
2-C ₆ H ₅ COC ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr (large excess)	1,3,3-Triphenyl-1-phthalanol* (90%)	145,146
Ethyl 9-Hydroxy-9-fluorene-9-carboxylate	CH ₃ MgI (7-8 equiv.)	α,α -Dimethyl- β -(<i>o,o'</i> -biphenylene)glycol (<i>ca.</i> quant.)	280

* Pérard, *Ann. chim.*, [9], 7, 344, footnote (1917), suggests that this product should be formulated as 2-C₆H₅COC₆H₄C(C₆H₅)₂OH.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₉O₃-R (cont.)			
Ethyl 9-Hydroxy-9-fluorene-9-carboxylate (21 g.)	C ₂ H ₅ MgBr (85 g. C ₂ H ₅ Br)	α, α -Diethyl- β -(<i>o-o'</i> -biphenylene)glycol (20 g.)	280
Ethyl 9-Hydroxy-9-fluorene-9-carboxylate (57 g.)	C ₆ H ₅ MgBr (178 g. C ₆ H ₅ Br)	α, α -Diphenyl- β -(<i>o,o'</i> -biphenylene)glycol (82%)	280
C₁₄H₁₁O₂-R			
(C ₆ H ₅) ₂ CHCO ₂ C ₂ H ₅ (17.5 g., 0.073 mole)	<i>i</i> -C ₃ H ₇ MgBr (0.073 mole) [+ C ₆ H ₅ COCl (14.0 g., 0.1 mole)]	C ₆ H ₅ CO(C ₆ H ₅) ₂ CCO ₂ C ₂ H ₅ (3.5 g., 14%); recovered ester	153
(C ₆ H ₅) ₂ CHCO ₂ C ₂ H ₅ (5.5 g.)	(CH ₂) ₅ CHMgCl (12.0 g. C ₆ H ₁₁ Cl)	Recovered ester	305
(C ₆ H ₅) ₂ CHCO ₂ C ₂ H ₅ (48 g.)	C ₆ H ₅ CH ₂ MgCl (102 g. C ₇ H ₇ Cl)	(C ₆ H ₅) ₂ CH(C ₆ H ₅ CH ₂) ₂ COH (65 g., 86%)	311
(C ₆ H ₅) ₂ CHCO ₂ CH ₂ CH=CH ₂ (25.0 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (25.0 g. C ₉ H ₁₁ Br)	Rec. ester (5.4 g.); 1,3,5-(CH ₃) ₃ C ₆ H ₃ (9.5 g., 63%); H ₂ C=CHCH ₂ C(C ₆ H ₅) ₂ CO ₂ H (11.9 g.)	514
(C ₆ H ₅) ₂ CHCO ₂ CH ₂ CH=CHCH ₃ (12.5 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (12.0 g. C ₉ H ₁₁ Br)	1,3,5-(CH ₃) ₃ C ₆ H ₃ (5.0 g.); H ₂ C=CHCH(CH ₃)C(C ₆ H ₅) ₂ CO ₂ H (8.2 g. 65.5%)	514
(C ₆ H ₅) ₂ CHCO ₂ CH(CH ₃)CH=CH ₂ (11.5 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (10.75 g. C ₉ H ₁₁ Br)	Rec. ester (0.9 g.); 1,3,5-(CH ₃) ₃ C ₆ H ₃ (4.6 g., 88.4%); CH ₃ CH=CHCH ₂ C(C ₆ H ₅) ₂ CO ₂ H (8.5 g., 74%)	514
2-C ₆ H ₅ CH ₂ C ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr	2-C ₆ H ₅ CH ₂ C ₆ H ₄ C(C ₆ H ₅) ₂ OH*; [HO(C ₆ H ₅)(2-C ₆ H ₅ CH ₂ C ₆ H ₄)C—] ₂ †	25
2-C ₆ H ₅ CH ₂ C ₆ H ₄ CO ₂ C ₂ H ₅ (32 g.)	C ₆ H ₅ MgBr (48 g. C ₆ H ₅ Br)	2-C ₆ H ₅ CH ₂ C ₆ H ₄ C(C ₆ H ₅) ₂ OH* (yielding 18 g. anthracene deriv.); [HO(C ₆ H ₅)(2-C ₆ H ₅ CH ₂ C ₆ H ₄)C—] ₂ † (15 g.)	25

* Isolated, after treatment with acetic acid, as 9,9-diphenyl-9,10-dihydroanthracene.

† In a private communication to Boyd and Hatt, *J. Chem. Soc.*, 1927, 909, Barnett states that when filtered (*i.e.*, Mg-free) Grignatd reagent solutions were used no glycols were detected.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₁O₂-R (cont.)			
2-C ₆ H ₅ CH ₂ C ₆ H ₄ CO ₂ C ₂ H ₅	4-CH ₃ OC ₆ H ₄ MgI	2-C ₆ H ₅ CH ₂ C ₆ H ₄ (4-CH ₃ OC ₆ H ₄) ₂ COH	51
2-C ₆ H ₅ CH ₂ C ₆ H ₄ CO ₂ C ₆ H ₅	C ₆ H ₅ MgBr	2-C ₆ H ₅ CH ₂ C ₆ H ₄ C(C ₆ H ₅) ₂ OH* [HO(C ₆ H ₅)(2-C ₆ H ₅ CH ₂ C ₆ H ₄)C—] ₂ †	25
C₁₄H₁₁O₃-R			
(C ₆ H ₅) ₂ C(OH)CO ₂ CH ₃ (1.0 g.)	C ₆ H ₅ MgBr (5.0 g. C ₆ H ₅ Br)	[HO(C ₆ H ₅) ₂ C—] ₂ (1.3 g.)	1
(C ₆ H ₅) ₂ C(OH)CO ₂ CH ₃ (10 g.)	(CH ₂) ₅ CHMgCl (60 g. C ₆ H ₁₁ Cl)	(C ₆ H ₅) ₂ C(OH)COCH(CH ₂) ₅	304
C₁₄H₁₂O₂N-R			
2- <i>p</i> -CH ₃ C ₆ H ₄ NHC ₆ H ₄ CO ₂ CH ₃ (15 g.)	C ₆ H ₅ MgBr (60 g. C ₆ H ₅ Br)	2- <i>p</i> -CH ₃ C ₆ H ₄ NHC ₆ H ₄ C(C ₆ H ₅) ₂ OH (75-80%)	513
C₁₄H₁₂O₃N-R			
2- <i>p</i> -CH ₃ OC ₆ H ₄ NHC ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr	2- <i>p</i> -CH ₃ OC ₆ H ₄ NHC ₆ H ₄ C(C ₆ H ₅) ₂ OH (75%)	513
C₁₄H₁₉O₃-R			
<i>i</i> -C ₅ H ₁₁ O(4-CH ₃ OC ₆ H ₄)CHCO ₂ - <i>i</i> -C ₅ H ₁₁	C ₂ H ₅ MgBr	<i>i</i> -C ₅ H ₁₁ O(4-CH ₃ OC ₆ H ₄)CHC(C ₂ H ₅) ₂ OH (yielding 60-70% 4-anisyl-3-hexanone)	367
C₁₄H₂₇O₃-R			
<i>n</i> -C ₁₃ H ₂₇ CO ₂ CH ₃ (77 g., 0.32 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.08 mole)	After alkaline hydrolysis, (<i>n</i> -C ₁₃ H ₂₇) ₂ CO (27.5 g., 44%); <i>n</i> -C ₁₃ H ₂₇ CO ₂ H (6.0 g., 8%); <i>t</i> -C ₄ H ₉ (<i>n</i> -C ₁₃ H ₂₇)CHOH (37.0 g., 40%); <i>i</i> -C ₄ H ₈ (0.09 mole); <i>i</i> -C ₄ H ₁₀ (0.17 mole)	476

* Isolated, after treatment with acetic acid, as 9,9-diphenyl-9,10-dihydroanthracene.

† In a private communication to Boyd and Hatt, *J. Chem. Soc.*, 1927, 909, Barnett states that when filtered (*i.e.*, Mg-free) Grignard reagent solutions were used no glycols were detected.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₂₇O₃-R (cont.)			
<i>n</i> -C ₁₃ H ₂₇ CO ₂ CH ₃	<i>n</i> -C ₈ H ₁₇ MgBr (2.5 equiv.)	<i>n</i> -C ₁₃ H ₂₇ (<i>n</i> -C ₈ H ₁₇) ₂ COH	460
<i>n</i> -C ₁₃ H ₂₇ CO ₂ C ₂ H ₅ (313 g.)	CH ₃ MgI (380 g. CH ₃ I)	<i>n</i> -C ₁₃ H ₂₇ (CH ₃) ₂ COH (220 g.)	330
C₁₅H₁₁O₂-R			
C ₆ H ₅ CH=C(C ₆ H ₅)CO ₂ CH ₃ (42.0 g.)	CH ₃ MgI (12.7 g. Mg)	C ₆ H ₅ CH=C(C ₆ H ₅)C(CH ₃) ₂ OH (21.0 g., 50%)	210,217
C ₆ H ₅ CH=C(C ₆ H ₅)CO ₂ CH ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH(C ₆ H ₅)CO ₂ CH ₃	217,211
C ₆ H ₅ CH=C(C ₆ H ₅)CO ₂ CH ₃	2-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ (2-CH ₃ C ₆ H ₄)CHCH(C ₆ H ₅)CO ₂ CH ₃	217
C ₆ H ₅ CH=C(C ₆ H ₅)CO ₂ CH ₃	1-C ₁₀ H ₇ MgBr	C ₆ H ₅ (1-C ₁₀ H ₇)CHCH(C ₆ H ₅)CO ₂ CH ₃	217
C ₆ H ₅ CH=C(C ₆ H ₅)CO ₂ C ₆ H ₅	C ₆ H ₅ MgBr (excess)	(C ₆ H ₅) ₂ CHCH(C ₆ H ₅)COC ₆ H ₅	218
C₁₅H₁₁O₃-R			
(C ₆ H ₅) ₂ CHCOCO ₂ C ₂ H ₅	C ₆ H ₅ MgBr (excess)	(C ₆ H ₅) ₂ CHC(OH)(C ₆ H ₅)CO ₂ C ₂ H ₅ (8 g.; inverse add'n, 10 g.)*	221
(C ₆ H ₅) ₂ CHCOCO ₂ C ₂ H ₅	C ₆ H ₅ MgBr ("large excess")	(C ₆ H ₅) ₂ CHC(OH)(C ₆ H ₅)COC ₆ H ₅ ; (C ₆ H ₅) ₂ CHC(OH)(C ₆ H ₅)C(C ₆ H ₅) ₂ OH†	221
Ethyl β,β-diphenylglycidate	C ₆ H ₅ MgBr ("large excess")	(C ₆ H ₅) ₃ COH; (C ₆ H ₅) ₂ CHCHO; (C ₆ H ₅ —) ₂	221
Ethyl 9-xanthylacetate	C ₆ H ₅ MgBr (3 equiv.)	1,1-Diphenyl-2-(9-xanthyl)ethanol ("good yield")	475
C₁₅H₁₁O₄-R			
2-(2-CH ₃ OC ₆ H ₄ CO)C ₆ H ₄ CO ₂ C ₂ H ₅ (20.3 g.)	4-CH ₃ OC ₆ H ₄ MgI (46.8 g. C ₇ H ₇ IO)	2-(2-CH ₃ OC ₆ H ₄ CO)C ₆ H ₄ (4-CH ₃ OC ₆ H ₄) ₂ COH (22.7 g.)	51
2-(4-CH ₃ OC ₆ H ₄ CO)C ₆ H ₄ CO ₂ CH ₃	4-CH ₃ OC ₆ H ₄ MgI	2-(4-CH ₃ OC ₆ H ₄ CO)C ₆ H ₄ COC ₆ H ₄ -4-OCH ₃	52
C₁₅H₁₂O₃N-R			
C ₆ H ₅ (C ₆ H ₅ CO)NCH ₂ CO ₂ C ₂ H ₅	CH ₃ MgBr	C ₆ H ₅ (C ₆ H ₅ CO)NCH ₂ C(CH ₃) ₂ OH	45

* Addition of Et₂O-ester solution to ice-cooled Grignard reagent solution.

† Addition of Et₂O-ester solution to Grignard reagent solution; several days at room temperature, or three to four hours reflux.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₂O₃N-R (cont.)			
C ₆ H ₅ CONHCH(C ₆ H ₅)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	C ₆ H ₅ CONHCH(C ₆ H ₅)C(C ₂ H ₅) ₂ OH (82%)	417
C₁₅H₁₃O₂-R			
CH ₃ (C ₆ H ₅) ₂ CCO ₂ CH ₂ CH=CH ₂ (5.07 g.)	C ₆ H ₅ MgBr (5.25 ml. C ₆ H ₅ Br)	CH ₃ (C ₆ H ₅) ₂ CCO ₂ H (3.8 g., 88%)	6
C ₆ H ₅ (C ₆ H ₅ CH ₂)CHCO ₂ CH ₃	C ₆ H ₅ CH ₂ MgCl (3 equiv.)	C ₆ H ₅ (C ₆ H ₅ CH ₂)CH(C ₆ H ₅ CH ₂) ₂ COH	312
C₁₅H₁₃O₃-R			
CH ₃ O(C ₆ H ₅) ₂ CCO ₂ CH ₃ (70 g.) HO(C ₆ H ₅) ₂ CCH ₂ CO ₂ C ₂ H ₅	CH ₃ MgI (3 equiv.) CH ₃ MgI	CH ₃ O(C ₆ H ₅) ₂ CC(CH ₃) ₂ OH (60 g.) HO(C ₆ H ₅) ₂ CCH ₂ C(CH ₃) ₂ OH; (C ₆ H ₅) ₂ C=C=C(CH ₃) ₂	280
HO(C ₆ H ₅) ₂ CCH ₂ CO ₂ C ₂ H ₅	C ₂ H ₅ MgI	HO(C ₆ H ₅) ₂ CCH ₂ C(C ₂ H ₅) ₂ OH	35
HO(C ₆ H ₅) ₂ CCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	[HO(C ₆ H ₅) ₂ C] ₂ CH ₂	35
2-(4-CH ₃ OC ₆ H ₄ CH ₂)C ₆ H ₄ CO ₂ C ₂ H ₅ (23 g.)	2-CH ₃ OC ₆ H ₄ MgI (50 g. C ₇ H ₇ IO)	2-(4-CH ₃ OC ₆ H ₄ CH ₂)C ₆ H ₄ (2-CH ₃ OC ₆ H ₄) ₂ COH (26 g.)	51
2-(4-CH ₃ OC ₆ H ₄ CH ₂)C ₆ H ₄ CO ₂ C ₂ H ₅ (20.3 g.)	4-CH ₃ OC ₆ H ₄ MgI (46.8 g. C ₇ H ₇ IO)	2-(4-CH ₃ OC ₆ H ₄ CH ₂)C ₆ H ₄ (4-CH ₃ OC ₆ H ₄) ₂ COH (17 g.)	51, 53
C₁₅H₁₅O₂N₂-R			
2- <i>p</i> -(CH ₃) ₂ NC ₆ H ₄ NHC ₆ H ₄ CO ₂ CH ₃ (1.35 g.)	C ₆ H ₅ MgBr (4.80 g. C ₆ H ₅ Br)	2- <i>p</i> -(CH ₃) ₂ NC ₆ H ₄ NHC ₆ H ₄ C(C ₆ H ₅) ₂ OH	508
C₁₅H₁₆O₂N₃-R			
2- <i>p</i> -(CH ₃) ₂ NC ₆ H ₄ NH-5- H ₂ NC ₆ H ₃ CO ₂ CH ₃ (0.5 g.)	CH ₃ MgI (3.9 g. CH ₃ I)	2- <i>p</i> -(CH ₃) ₂ NC ₆ H ₄ NH-5-H ₂ NC ₆ H ₃ C(CH ₃) ₂ OH (yielding 70% of the carbazine dihydrochloride)	511
2- <i>p</i> -(CH ₃) ₂ NC ₆ H ₄ NH-5- H ₂ NC ₆ H ₃ CO ₂ CH ₃	C ₂ H ₅ MgBr	2- <i>p</i> -(CH ₃) ₂ NC ₆ H ₄ NH-5-H ₂ NC ₆ H ₃ C(C ₂ H ₅) ₂ OH (yielding 65% of the carbazine dihydrochloride)	512

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₆O₂N₃-R (<i>cont.</i>)			
2- <i>p</i> -(CH ₃) ₂ NC ₆ H ₄ NH-5- H ₂ NC ₆ H ₃ CO ₂ CH ₃	C ₆ H ₅ MgBr (6.2 g. C ₆ H ₅ Br)	2- <i>p</i> -(CH ₃) ₂ NC ₆ H ₄ NH-5-H ₂ NC ₆ H ₃ C(C ₆ H ₅) ₂ OH	508
C₁₅H₂₃O₂-R			
Ethyl homoaleprate*	C ₆ H ₅ MgBr ("large excess")	C ₅ H ₇ (CH ₂) ₉ C(C ₆ H ₅) ₂ OH	71
C₁₆H₁₀O₂N-R			
Acitrin†	CH ₃ MgI	α, α -Dimethyl-2-phenyl-4-quinolinemethanol	103
Acitrin†	C ₂ H ₅ MgI	α, α -Diethyl-2-phenyl-4-quinolinemethanol	111
Acitrin†	C ₆ H ₅ MgBr	$\alpha, \alpha, 2$ -Triphenyl-4-quinolinemethanol; pinacol (?), m. 196°; C ₃₈ H ₂₆ ON ₂ (?), m. 202-3°	482
Acitrin†	C ₆ H ₅ CH ₂ MgCl	α, α -Dibenzyl-2-phenyl-4-quinolinemethanol	103
Acitrin†	3-CH ₃ C ₆ H ₄ MgBr	α, α -Di- <i>m</i> -tolyl-2-phenyl-4-quinolinemethanol	103
C₁₆H₁₃O₂-R			
(C ₆ H ₅) ₂ C=C(CH ₃)CO ₂ C ₂ H ₅ (23.0 g.)	C ₆ H ₅ MgBr (27.1 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ C=C(CH ₃)C(C ₆ H ₅) ₂ OH (3.5 g.)	41
Methyl 1-methyl-3- phenanthrenecarboxylate	CH ₃ MgBr	$\alpha, \alpha, 1$ -Trimethyl-3-phenanthrenemethanol	93
Methyl 3-phenyl-1- indancarboxylate (6.7 g.)	C ₆ H ₅ MgBr (8.5 ml. C ₆ H ₅ Br)	$\alpha, \alpha, 3$ -Triphenyl-1-indanmethanol (3.5 g.)	54
C₁₆H₁₄O₃N-R			
C ₆ H ₅ CONH(C ₆ H ₅ CH ₂)CHCO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	C ₆ H ₅ CONH(C ₆ H ₅ CH ₂)CHC(C ₂ H ₅)OH (69%)	45

* Ethyl 10-(Δ^2 -cyclopentenyl)decanoate.

† Ethyl 2-phenylcinchonimate; ethyl 2-phenyl-4-quinolinecarboxylate.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₁₅O₂-R			
CH ₃ (C ₆ H ₅) ₂ CCH ₂ CO ₂ C ₂ H ₅	CH ₃ MgI	CH ₃ (C ₆ H ₅) ₂ CCH ₂ C(CH ₃) ₂ OH (65%)	40
(C ₆ H ₅) ₂ CHCH(CH ₃)CO ₂ CH ₃ (25 g.)	C ₆ H ₅ MgBr (125 ml., 2M)	(C ₆ H ₅) ₂ CHCH(CH ₃)C(C ₆ H ₅) ₂ OH (yielding 15 g., 43% olefin)	209
C₁₆H₁₅O₃-R			
HO(C ₆ H ₅)(4-CH ₃ C ₆ H ₄)CCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	HO(C ₆ H ₅)(4-CH ₃ C ₆ H ₄)CCH ₂ C(C ₆ H ₅) ₂ OH	35
C₁₆H₁₅O₄-R			
HO(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)CCH ₂ CO ₂ C ₂ H ₅	CH ₃ MgI	HO(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)CCH ₂ C(CH ₃) ₂ OH	35
HO(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)CCH ₂ CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	HO(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)CCH ₂ C(C ₆ H ₅) ₂ OH	35
C₁₆H₁₇O₂-R			
Methyl 1-methyl-1,2,3,4-tetrahydro-3-phenanthrenecarboxylate	CH ₃ MgBr	$\alpha, \alpha, 1$ -Trimethyl-1,2,3,4-tetrahydro-3-phenanthrenemethanol	93
C₁₆H₁₉O₃-R			
Methyl 2-o-anisyl-4,5-dimethyl-4-cyclohexene-1-carboxylate	CH ₃ MgI	$\alpha, \alpha, 4, 5$ -Tetramethyl-2-o-anisyl-4-cyclohexene-1-methanol (91%)	279
C₁₆H₂₃O₂-R			
2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	CH ₃ MgI	2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ COCH ₃ (46%); 4-CH ₃ C ₆ H ₄ OH (78%)	120
2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	C ₂ H ₅ MgBr	2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ COCH ₂ CH ₃ (43%); 4-CH ₃ C ₆ H ₄ OH	120
2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ CO ₂ C ₆ H ₄ -4-CH ₃	C ₆ H ₅ MgBr	1,4-[2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ CO] ₂ C ₆ H ₄ ; 4-CH ₃ C ₆ H ₄ OH	119

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₂₇O₂-R			
Ethyl hydnocarpate* (9 g.)	C ₂ H ₅ MgBr	C ₅ H ₇ (CH ₂) ₁₀ C(C ₂ H ₅) ₂ OH (ca. 9 g.)	71
Ethyl hydnocarpate* (8 g.)	H ₂ C=CHCH ₂ MgBr	C ₅ H ₇ (CH ₂) ₁₀ C(CH ₂ CH=CH ₂) ₂ OH (yielding 4-5 g. dehydrate)	71
Ethyl hydnocarpate* (9 g.)	<i>n</i> -C ₃ H ₇ MgBr (10 g. C ₃ H ₇ Br)	C ₅ H ₇ (CH ₂) ₁₀ C(<i>n</i> -C ₃ H ₇) ₂ OH (ca. 11 g.)	71
Ethyl hydnocarpate* (50 g.)	C ₆ H ₅ MgBr (70 g. C ₆ H ₅ Br)	C ₅ H ₇ (CH ₂) ₁₀ C(C ₆ H ₅) ₂ OH (yielding 55 g. olefin)	71
C₁₆H₃₁O₂-R			
<i>n</i> -C ₁₅ H ₃₁ CO ₂ CH ₃	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₁₅ H ₃₁)CHOH	238
<i>n</i> -C ₁₅ H ₃₁ CO ₂ CH ₃	C ₆ H ₅ MgBr	<i>n</i> -C ₁₅ H ₃₁ (C ₆ H ₅) ₂ COH (yielding 80-90% olefin)	377
<i>n</i> -C ₁₅ H ₃₁ CO ₂ CH ₃	<i>n</i> -C ₆ H ₁₃ MgBr (2.5 equiv.)	<i>n</i> -C ₁₅ H ₃₁ (<i>n</i> -C ₆ H ₁₃) ₂ COH	460
<i>n</i> -C ₁₅ H ₃₁ CO ₂ C ₂ H ₅	CH ₃ MgBr	<i>n</i> -C ₁₅ H ₃₁ (CH ₃) ₂ COH	229
<i>n</i> -C ₁₅ H ₃₁ CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	<i>n</i> -C ₁₅ H ₃₁ (C ₂ H ₅) ₂ COH (99%)	230
<i>n</i> -C ₁₅ H ₃₁ CO ₂ C ₂ H ₅	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₁₅ H ₃₁ (<i>n</i> -C ₃ H ₇) ₂ COH	226
<i>n</i> -C ₁₅ H ₃₁ CO ₂ C ₂ H ₅	<i>s</i> -C ₄ H ₉ MgBr	(<i>n</i> -C ₁₅ H ₃₁) ₂ CO	327
<i>n</i> -C ₁₅ H ₃₁ CO ₂ C ₂ H ₅ (50 g.)	<i>t</i> -C ₄ H ₉ MgCl (52 g. C ₄ H ₉ Cl)	(<i>n</i> -C ₁₅ H ₃₁) ₂ CO (25%)	326,327
C₁₇H₁₂O₂N-R			
2-β-C ₁₀ H ₇ NHC ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr	2-β-C ₁₀ H ₇ NHC ₆ H ₄ C(C ₆ H ₅) ₂ OH (75%)	513
Ethyl 2-phenyl-6-methyl-cinchoninate,†	C ₂ H ₅ MgBr	α,α-Diethyl-2-phenyl-6-methyl-4-quinolinemethanol	111
C₁₇H₁₃O₂-R			
C ₆ H ₅ CH=CHCH=C(C ₆ H ₅)CO ₂ CH ₃	CH ₃ MgI (4 equiv.)	C ₆ H ₅ CH=CHCH=C(C ₆ H ₅)C(CH ₃) ₂ OH; C ₆ H ₅ CH=CHCH=C(C ₆ H ₅)C(CH ₃)=CH ₂	353

* Ethyl 11-(Δ²-cyclopentenyl)undecanoate.

† Ethyl 2-phenyl-6-methyl-4-quinolinecarboxylate.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₁₃O₂-R (cont.)			
C ₆ H ₅ CH=CHC(C ₆ H ₅)=CHCO ₂ CH ₃	C ₆ H ₅ MgBr	C ₆ H ₅ CH=CHC(C ₆ H ₅)=CHC(C ₆ H ₅) ₂ OH (40%); oil	214
C ₆ H ₅ CH=CHCH=C(C ₆ H ₅)CO ₂ CH ₃	C ₆ H ₅ MgBr (3 equiv.)	C ₆ H ₅ CH=CHCH(C ₆ H ₅)CH(C ₆ H ₅)COC ₆ H ₅	353
C ₆ H ₅ CH=CHCH=C(C ₆ H ₅)CO ₂ CH ₃	C ₆ H ₅ CH ₂ MgBr (3 equiv.)	C ₆ H ₅ CH=CHCH(CH ₂ C ₆ H ₅)CH(C ₆ H ₅)COCH ₂ C ₆ H ₅ (17%)	353
C ₆ H ₅ CH=CHCH=C(C ₆ H ₅)CO ₂ CH ₃	2-CH ₃ C ₆ H ₄ MgBr (3 equiv.)	Recovered ester (as acid); C ₇ H ₈ (65%); unidentified oil	353
C ₆ H ₅ CH=CHCH=C(C ₆ H ₅)CO ₂ CH ₃	1-C ₁₀ H ₇ MgBr (3 equiv.)	Recovered ester (as acid); C ₁₀ H ₈ ; tar	353
C₁₇H₁₅O₄N₂-R			
C ₆ H ₅ CONHCH ₂ CONHCH(C ₆ H ₅)-CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ CONHCH ₂ CONHCH(C ₆ H ₅)C(C ₆ H ₅) ₂ OH	45
C ₆ H ₅ CONHCH ₂ CONHCH(C ₆ H ₅)-CO ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgBr	C ₆ H ₅ CONHCH ₂ CONHCH(C ₆ H ₅)C(CH ₂ C ₆ H ₅) ₂ OH	45
C₁₇H₁₉O₂N₂-R			
2- <i>p</i> -(C ₂ H ₅) ₂ NC ₆ H ₄ NHC ₆ H ₄ CO ₂ CH ₃ (0.2 g.)	C ₆ H ₅ MgBr (1.5 g. C ₆ H ₅ Br)	2- <i>p</i> -(C ₂ H ₅) ₂ NC ₆ H ₄ NHC ₆ H ₄ C(C ₆ H ₅) ₂ OH	509
C₁₇H₂₀O₂N₃-R			
2- <i>p</i> -(C ₂ H ₅) ₂ NC ₆ H ₃ NH5-H ₂ NC ₆ H ₄ CO ₂ CH ₃ (0.5 g.)	C ₆ H ₅ MgBr (2.2 g. C ₆ H ₅ Br)	2- <i>p</i> -(C ₂ H ₅) ₂ NC ₆ H ₄ NH-5-H ₂ NC ₆ H ₃ C(C ₆ H ₅) ₂ OH	509
C₁₈H₁₁O₃-R			
2-C ₆ H ₅ CO ₂ C ₁₀ H ₆ -1-CO ₂ CH ₃	CH ₃ MgI (ca. 1 equiv.)	3-Methyl-3-phenyl-6,7-benzophthalide (56%)	106

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₈H₁₄O₄-R₂			
Diethyl γ -truxillate* (20.0 g.)	CH ₃ MgI (32.3 g. CH ₃ I)	γ -2,4-Diphenyl-3-(α -hydroxyisopropyl)-1-cyclobutanecarboxylic acid lactone; $\alpha, \alpha, \alpha', \alpha'$ -tetramethyl-2,4-diphenyl-1,3-cyclobutanedimethanol; 1,3-diisopropylidene-2,4-diphenylcyclobutane	409
C₁₈H₁₅O₄-R			
Monoethyl α -truxillate† (18.8 g.)	CH ₃ MgI (33.0 g. CH ₃ I)	α -2,4-Diphenyl-3-(α -hydroxyisopropyl)-1-cyclobutanecarboxylic acid ("good yield")	409
Monoethyl γ -truxillate‡ (15 g.)	C ₂ H ₅ MgBr (28 g. C ₂ H ₅ Br)	γ -2,4-Diphenyl-3-(3-hydroxy-3-amy)-1-cyclobutanecarboxylic acid	409
C₁₈H₂₀O₅-R₂			
Dimethyl (+) β -7-methyl-marrianolate‡	C ₆ H ₅ MgBr	(+) β -2'-Hydroxy-2',2'-diphenyl-7-methyldoisynolic acid lactone§	46
C₁₈H₃₁O₂-R			
Ethyl chaulmoograte¶ (9 g.)	CH ₃ MgI (10 g. CH ₃ I)	C ₅ H ₇ (CH ₂) ₁₂ C(CH ₃) ₂ OH (90%)	71
Ethyl chaulmoograte¶	1-C ₁₀ H ₇ MgBr (3 equiv.)	C ₅ H ₇ (CH ₂) ₁₁ CH=C(1-C ₁₀ H ₇) ₂	71
C₁₈H₃₂O₄-R₂			
[—(CH ₂) ₈ CO ₂ CH ₃] ₂	C ₆ H ₅ MgBr	[—(CH ₂) ₈ C(C ₆ H ₅) ₂ OH] ₂ (ca. 80%)	377

* Diethyl 2,4-diphenyl-1,3-cyclobutanedicarboxylate.

† 2,4-Diphenyl-3-carbethoxy-1-cyclobutanecarboxylic acid.

‡ 1-Carbomethoxymethyl-2-carbomethoxy-7-methoxy-1,2,3,4,4a,9,10,10a-octahydrophenanthrene.

§ 1-Oxo-3,3-diphenyl-8-methoxy-3,4,4a,4b,5,6,10b,11,12,12a-decahydro-1-phenanthro[2,1-c]pyran.

¶ Ethyl 13-(Δ^2 -cyclopentenyl)tridecanoate.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₈H₃₂O₄-R₂ (cont.) [—(CH ₂) ₈ CO ₂ C ₂ H ₅] ₂	CH ₃ MgBr	[—(CH ₂) ₈ C(CH ₃) ₂ OH] ₂	228
C₁₈H₃₂O₂-R CH ₃ (CH ₂) ₇ CH=CH(CH ₂) ₇ CO ₂ CH ₃ (296 g.)	<i>n</i> -C ₄ H ₉ MgBr (685 g. C ₄ H ₉ Br)	C ₁₇ H ₃₃ (<i>n</i> -C ₄ H ₉) ₂ COH	460
C₁₈H₃₅O₂-R <i>n</i> -C ₁₇ H ₃₅ CO ₂ CH ₃ <i>n</i> -C ₁₇ H ₃₅ CO ₂ CH ₃ <i>n</i> -C ₁₇ H ₃₅ CO ₂ C ₂ H ₅ (0.1 mole)	CH ₃ MgI C ₆ H ₅ MgBr 2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (0.1 mole)	<i>n</i> -C ₁₇ H ₃₅ (CH ₃) ₂ COH <i>n</i> -C ₁₇ H ₃₅ (C ₆ H ₅) ₂ COH (yielding 80-90% olefin) <i>n</i> -C ₁₇ H ₃₅ CO(<i>n</i> -C ₁₆ H ₃₃)CHCO ₂ C ₂ H ₅ (27%)	283 377 396
C₁₉H₁₉O₃-R 2-o-CH ₃ C ₆ H ₄ COC ₁₀ H ₆ -1-CO ₂ CH ₃	CH ₃ MgI (ca. 1 equiv.)	3-Methyl-3-o-tolyl-6,7-benzophthalide (51%, on basis of ester consumed)	106
C₁₉H₁₉O₅Br-R₂ Dimethyl 2-benzoyl-3-(3-bromo-4-methoxyphenyl)-1,1-cyclopropanedicarboxylate Dimethyl 2-benzoyl-3-(3-bromo-4-methoxyphenyl)-1,1-cyclopropanedicarboxylate Dimethyl 2-benzoyl-3-(3-bromo-4-methoxyphenyl)-1,1-cyclopropanedicarboxylate	C ₂ H ₅ MgBr C ₆ H ₅ MgBr (4 equiv.) C ₆ H ₅ MgBr	Dimethyl 2-(α -hydroxy- α -phenylpropyl)-3-(3-bromo-4-methoxyphenyl)-1,1-cyclopropanedicarboxylate (2 isomers, m. 135° and 161°) Dimethyl α -benzoyl- β -phenyl- β -(3-bromo-4-methoxyphenyl)ethylmalonate (30%)* Methyl 1,2-dibenzoyl-3-(3-bromo-4-methoxyphenyl)-1-cyclopropanedicarboxylate†	215 215 215

* Gradual addition of powdered ester to agitated, ice-cold Grignard reagent solution.

† Gradual addition of Grignard reagent solution to agitated C₆H₅ ester solution at 35°.

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₀H₁₁O₃-R			
Methyl 2-phenyl-9-oxo-1-fluorene-9-carboxylate (3.1 g.)	C ₆ H ₅ MgBr (15.6 g. C ₆ H ₅ Br)	1-Benzoyl-2-phenyl-9-fluorenone (1.0 g.)	449
C₂₀H₁₃O₃-R			
Methyl 2-(9-xanthyl)benzoate (6.0 g.)	C ₆ H ₅ MgBr (9.0 g. C ₆ H ₅ Br)	2-(9-Xanthyl)triphenylmethanol (4.5 g.)	484
C₂₀H₁₅O₂-R			
(C ₆ H ₅) ₃ CCO ₂ CH ₂ CH=CH ₂ (3.8 g.)	C ₆ H ₅ MgBr (2.6 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ CCO ₂ H (3.1 g., 93%)	6
2-[(C ₆ H ₅) ₂ CH]C ₆ H ₄ CO ₂ CH ₃ (5.0 g.)	CH ₃ MgI (5.9 g. CH ₃ I)	2-[(C ₆ H ₅) ₂ CH]C ₆ H ₄ C(CH ₃) ₂ OH*	65
2-[(C ₆ H ₅) ₂ CH]C ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr	2-[(C ₆ H ₅) ₂ CH]C ₆ H ₄ C(C ₆ H ₅) ₂ OCH ₃	148
2-[(C ₆ H ₅) ₂ CH]C ₆ H ₄ CO ₂ CH ₃	C ₆ H ₅ MgBr (2 equiv.)	2-[(C ₆ H ₅) ₂ CH]C ₆ H ₄ C(C ₆ H ₅) ₂ OH	25
C₂₀H₁₇O₅N-R₂			
Diethyl 1-methyl-2,6-diphenyl-4-oxo-3,5-pyridinedicarboxylate (3.1 g.)	C ₂ H ₅ MgI (1.2 g. C ₂ H ₅ I)	Diethyl 1-methyl-2,6-diphenyl-4-hydroxy-4-ethyl-3,5-pyridinedicarboxylate (3.0 g.)	485
Diethyl 1-methyl-2,6-diphenyl-4-oxo-3,5-pyridinedicarboxylate (3.0 g.)	<i>n</i> -C ₃ H ₇ MgBr (1.0 g. C ₃ H ₇ Br)	Diethyl 1-methyl-2,6-diphenyl-4-hydroxy-4- <i>n</i> -propyl-3,5-pyridinedicarboxylate (3.1 g.)	485
Diethyl 1-methyl-2,6-diphenyl-4-oxo-3,5-pyridinedicarboxylate (3.0 g.)	<i>n</i> -C ₄ H ₉ MgBr	Diethyl 1-methyl-2,6-diphenyl-4-hydroxy-4- <i>n</i> -butyl-3,5-pyridinedicarboxylate (3.1 g.)	485
Diethyl 1-methyl-2,6-diphenyl-4-oxo-3,5-pyridinedicarboxylate (6.0 g.)	C ₆ H ₅ MgBr (2.4 g. C ₆ H ₅ Br)	Diethyl 1-methyl-2,4,6-triphenyl-4-hydroxy-3,5-pyridinedicarboxylate (6.5 g.)	485

* Isolated, after AlCl₃ cyclization, as 9,9-dimethyl-10-phenyl-9,10-dihydroanthracene (0.75 g., 16%).

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₀H₁₉O₅-R CH ₃ CO ₂ (C ₂ H ₅ O)C = C[CH(C ₆ H ₅) ₂]CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr (2 equiv.)	(C ₆ H ₅) ₂ CHCH(CO ₂ C ₂ H ₅) ₂ ; CH ₃ (C ₆ H ₅) ₂ COH	212
C₂₀H₂₁O₃-R C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)C = C(C ₂ H ₅)C ₆ H ₄ -3-CO ₂ CH ₃	CH ₃ MgI (1.33 equiv.)	C ₂ H ₅ (4-CH ₃ OC ₆ H ₄)C = C(C ₂ H ₅)C ₆ H ₄ -3-COCH ₃	483
C₂₁H₁₇O₃-R (C ₆ H ₅) ₂ CHC(OH)(C ₆ H ₅)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr ("large excess")	(C ₆ H ₅) ₂ CHC(OH)(C ₆ H ₅)COC ₆ H ₅ ; (C ₆ H ₅) ₂ CHC(OH)(C ₆ H ₅)C(C ₆ H ₅) ₂ OH	221
C₂₁H₁₉O₅N-R₂ Diethyl 1-ethyl-2,6-diphenyl-4-oxo-3,5-pyridinedicarboxylate (0.007 mole)	C ₂ H ₅ MgI (0.0075 mole)	Diethyl 1,4-diethyl-2,6-diphenyl-4-hydroxy-3,5-piperidinedicarboxylate (2.0 g.)	380
Diethyl 1-ethyl-2,6-diphenyl-4-oxo-3,5-pyridinedicarboxylate (0.01 mole)	C ₆ H ₅ MgBr (0.01 mole)	Diethyl 1-ethyl-2,4,6-triphenyl-4-hydroxy-3,5-piperidinedicarboxylate (2.5 g.)	380
C₂₁H₃₅O₃-R Methyl 3(α),11(α)-dihydroxy-bisnorcholanate (22.5 g., 0.06 mole)	C ₆ H ₅ MgBr (1.2 mole)	3(α),11(α)-Dihydroxytrischolanyldiphenylmethanol (yielding 18.4 g. crude olefin); recovered ester (as acid, 1.6 g., 7%)	247
C₂₂H₁₃O₃-R Methyl 4-(1-oxo-3-phenyl-2-indenyl)benzoate	C ₆ H ₅ MgBr (excess)	1,3-Diphenyl-2-(4-α-hydroxybenzhydrylphenyl)-1-indenol	208

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₂H₃₃O₃-R			
Methyl 3-hydroxy- Δ^5 -bisnorcholenate (12 g.)	C ₆ H ₅ MgBr (49 g. C ₆ H ₅ Br)	3-Hydroxy- Δ^5 -ternorcholenyldiphenylmethanol (<i>ca.</i> 11 g.)	406
C₂₂H₃₄O₂Cl-R			
Methyl 3-chlorobisnorallocholanate	C ₆ H ₅ MgBr	3-Chloroternorallocholanyldiphenylmethanol	253,254
C₂₂H₃₅O₂-R			
Ethyl α -bisnorcholanate	CH ₃ MgI	Ternorcholanyldimethylmethanol	465
C₂₂H₃₅O₄-R			
Methyl bisnordesoxycholate	C ₆ H ₅ MgBr (16 equiv.)	3,12-Dihydroxyternorcholanyldiphenylmethanol	165
Methyl 3(α),12(α)-dihydroxy-bisnorcholanate (4.5 g.)	C ₆ H ₅ MgBr	(3 α),12(α)-Dihydroxy-20-pregnyldiphenylmethanol (5.1 g.)	394
Methyl 3(α),12(β)-dihydroxy-bisnorcholanate (18 g.)	C ₆ H ₅ MgBr (69 ml. C ₆ H ₅ Br)	3(α),12(β)-Dihydroxy-20-pregnyldiphenylmethanol (22.3 g.)	351,394
Methyl 3(α),12(α)-dihydroxy-isobisnotcholanate (0.5 g.)	C ₆ H ₅ MgBr	3(α),12(α)-Dihydroxy-20-isopregnyldiphenylmethanol (440 mg.)	394
Methyl 3(α),12(β)-dihydroxy-isobisnorcholanate (440 mg.)	C ₆ H ₅ MgBr (2.5 ml. C ₆ H ₅ Br)	3(α),12(β)-Dihydroxy-20-isopregnyldiphenylmethanol (430 mg.)	394
C₂₂H₃₅O₅-R			
Methyl bisnorcholanate	CH ₃ MgI	3,7,12-Trihydroxyternorcholanyldimethylmethanol	313
Methyl bisnorcholanate (4.1 g.)	C ₆ H ₅ MgBr (28.0 g. C ₆ H ₅ Br)	3,7,12-Trihydroxyternorcholanyldiphenylmethanol (3.8 g.)	290
C₂₂H₄₁O₂-R			
CH ₃ (CH ₂) ₇ CH=CH(CH ₂) ₁₁ CO ₂ C ₂ H ₅ (40 g.)	C ₆ H ₅ MgBr (3 equiv.)	CH ₃ (CH ₂) ₇ CH=CH(CH ₂) ₁₀ CH=C(C ₆ H ₅) ₂ (25 g.)	72

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₂H₄₃O₂-R			
<i>n</i> -C ₂₁ H ₄₃ CO ₂ C ₂ H ₅	CH ₃ MgBr (2 equiv.)	<i>n</i> -C ₂₁ H ₄₃ (CH ₃) ₂ COH	229
C₂₃H₃₅O₄-R			
Methyl 3-acetoxyetiocholanate (1.35 g.)	C ₆ H ₅ MgBr (12.60 g. C ₆ H ₅ Br)	3-Hydroxynoretiocholanyldiphenylmethanol (1.80 g.)	92
C₂₃H₃₆O₂Cl-R			
Methyl 3-chloronorallocholanate	C ₆ H ₅ MgBr	3-Chlorobisporallocholanyldiphenylmethanol	253,254
C₂₃H₃₆O₃-R			
Methyl 3-methoxybisnor-5-cholenate (1.6 g.)	C ₆ H ₅ MgBr (6.7 g. C ₆ H ₅ Br)	3-Methoxyternor-5-cholenyldiphenylmethanol (1.8 g., 85%)	359
Methyl 6-methoxybisnorisocholenate (1.45 g.)	C ₆ H ₅ MgBr (6.08 g. C ₆ H ₅ Br)	6-Methoxyternorisocholenyldiphenylmethanol (1.12 g.)	359
C₂₃H₃₇O₂-R			
Ethyl norcholanate	CH ₃ MgI	Bisnorcholanyldimethylmethanol	465
Ethyl norcholanate	C ₆ H ₅ MgBr	Bisnorcholanyldiphenylmethanol	465
C₂₃H₃₇O₃-R			
Methyl norlithocholate	CH ₃ MgI	3-Hydroxybisnorcholanyldimethylmethanol	354
Methyl 3-hydroxyallocholanate (3.8 g.)	C ₆ H ₅ MgBr (23.0 g. C ₆ H ₅ Br)	3-Hydroxynorallocholanyldiphenylmethanol (5.0 g., crude)	92
Methyl 3(α),11(α)-dihydroxynor- cholanate (22.1 g., 0.056 mole)	C ₆ H ₅ MgBr (1.48 mole)	3(α),11(α)-Dihydroxybisnorcholanyldiphenyl- methanol (26.4 g., crude)	247
C₂₃H₃₇O₄-R			
Methyl nordesoxycholate	C ₆ H ₅ MgBr (16 equiv.)	3,12-Dihydroxybisnorcholanyldiphenylmethanol	165

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₃H₃₇O₄-R (<i>cont.</i>)			
Methyl norhydrodesoxycholate (5 g., 0.105 mole)	C ₆ H ₅ MgBr (1.68 mole)	3(α),6(β)-Dihydroxybisnorchol- anyldiphenylmethanol (74%)	289
C₂₃H₃₇O₅-R			
Methyl norcholate (5 g.)	CH ₃ MgBr (15 g. CH ₃ Br)	3,7,12-Trihydroxybisnorcholanyldimethylmethanol (4 g.)	290
Methyl norcholate	CH ₃ MgI	3,7,12-Trihydroxybisnorcholanyldimethylmethanol	313
C₂₃H₄₀O₄-R			
Methyl chenodesoxycholate (5.0 g.)	CH ₃ MgI	"Tertiary carbinol" (2.5 g.)	180
C₂₄H₂₈O₄-R₂			
H ₃ CO ₂ CCH ₂ [CH=C(CH ₃)CH= CH] ₄ CH ₂ CO ₂ CH ₃ (1 g.)	CH ₃ MgI (60 equiv.)	HO(CH ₃) ₂ CCH ₂ [CH=C(CH ₃)CH= CH] ₄ CH ₂ C(CH ₃) ₂ OH	195
C₂₄H₃₇O₃-R			
Methyl 3-hydroxy-5-cholenate (5.5 g.)	C ₆ H ₅ MgBr (excess)	3-Hydroxy-5-norcholenyldiphenylmethanol (3.4 g.)	358
C₂₄H₃₇O₄-R			
Methyl 3-acetoxabisnorallo- cholanate (8.6 g.)	C ₆ H ₅ MgBr (55.0 g. C ₆ H ₅ Br)	3-Hydroxyternorcholanyldiphenylmethanol (12.2 g.)	92
C₂₄H₃₅O₂Cl-R			
Methyl 3-chloroallocholanate (27 g.)	C ₆ H ₅ MgBr (0.27 mole)	3-Chloronorallocholanyldiphenylmethanol (27 g.)	253,254

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₄H₃₆O₂Cl-R (cont.)			
Methyl <i>trans</i> (?)-3-chloroallocholanate (1.2 g.)	C ₆ H ₅ MgBr (1.5 g. C ₆ H ₅ Br)	Carbinol, isolated, after oxidation as <i>trans</i> (?)-3-chloronorallocholanolic acid	26
C₂₄H₃₉O₂-R			
Ethyl cholanate	CH ₃ MgI	Norcholanyldimethylmethanol (<i>ca.</i> quant.)	465
C₂₄H₃₉O₃-R			
Methyl lithocholate (3.9 g., 0.01 mole)	CH ₃ MgI (8.5 g., 0.06 mole CH ₃ I)	3-Hydroxynorcholanyldimethylmethanol (<i>ca.</i> 3.0 g.)	354
Methyl 3(α),11(α)-dihydroxycholanate (20 g., 0.05 mole)	C ₆ H ₅ MgBr (1.0 mole)	3(α),11(α)-Dihydroxynorcholanyldiphenylmethanol (22.4 g., crude); recovered ester (as acid, 3.2 g., 15%); 3(α),11(α)-dihydroxynorcholanyl phenyl ketone	247
C₂₄H₃₉O₄-R			
Methyl desoxycholate	C ₆ H ₅ MgBr (16 equiv.)	3,12-Dihydroxynorcholanyldiphenylmethanol (yielding 74% dehydrate)	165
Methyl hyodesoxycholate (1 kg.)	C ₆ H ₅ MgBr (39 moles)	3(α),6(β)-Dihydroxynorcholanyldiphenylmethanol (1035 g., crude)	289
C₂₄H₃₉O₅-R			
Methyl cholate (45 g.)	CH ₃ MgBr (<i>ca.</i> 105 g. CH ₃ Br)	3,7,12-Trihydroxynorcholanyldimethylmethanol (<i>ca.</i> 40 g.)	290
Methyl cholate	CH ₃ MgI	3,7,12-Trihydroxynorcholanyldimethylmethanol	313
Methyl cholate (50 g.)	C ₆ H ₅ MgBr (280 g. C ₆ H ₅ Br)	3,7,12-Trihydroxynorcholanyldiphenylmethanol (42 g.)	290

TABLE VIII-III (Continued)

<u>Ester</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₅H₃₉O₃-R			
Methyl 3-methoxy-5-cholenate (2.0 g.)	C ₆ H ₅ MgBr (excess)	3-Methoxy-5-norcholenyldiphenylmethanol (2.26 g., 96%)	358
Methyl 6(α)-methoxyisocholenate (2.69 g.)	C ₆ H ₅ MgBr (11.00 g. C ₆ H ₅ Br)	6(α)-Methoxynorisocholenyldiphenylmethanol (1.97 g., 57%)	358
C₂₅H₃₉O₄-R			
Methyl 3-acetoxynorallocholanate (18 g.)	C ₆ H ₅ MgBr (103 g. C ₆ H ₅ Br)	3-Hydroxynorcholanic acid (1 g.); 3-hydroxybisanorallocholanyldiphenylmethanol (27 g.)	92
C₂₅H₄₁O₅-R			
Methyl 25-homocholate (1062 mg.)	CH ₃ MgI	3,7,12,25-Tetrahydroxycholestane (252 mg.)	325
C₂₆H₁₇O₂-R			
Ethyl 9,9-diphenyl-4-fluorencarboxylate	C ₆ H ₅ MgBr	α,α,9,9-Tetraphenyl-4-fluorenemethanol	397
C₂₆H₁₉O₂-R			
2-(C ₆ H ₅) ₂ CHC ₆ H ₄ C ₆ H ₄ -2-CO ₂ CH ₃	C ₆ H ₅ MgBr	2-(C ₆ H ₅) ₂ CHC ₆ H ₄ C ₆ H ₄ -2-C(C ₆ H ₅) ₂ OH	397
C₂₈H₄₅O₂-R			
Methyl 5-cholestene-3-carboxylate (200 mg.)	CH ₃ MgI	α,α-Dimethyl-5-cholestene-3-methanol (200 mg.)	22
C₂₈H₅₂O₄-R₂			
[—(CH ₂) ₁₃ CO ₂ CH ₃] ₂	C ₆ H ₅ MgBr	[—(CH ₂) ₁₃ C(C ₆ H ₅) ₂ OH] ₂ (yielding 80-90% olefin)	377

REFERENCES FOR TABLE VIII-III

- (1) Acree, *Ber.*, 37, 2753-64 (1904).
- (2) Acree, *Am. Chem. J.*, 33, 180-95 (1905).
- (3) Alessandri, *Atti accad. Lincei*, [5], 24,II, 194-9 (1915); *Chem. Zentr.*, 1916,I, 1072.
- (4) Arnold, Bank, and Liggett, *J. Am. Chem. Soc.*, 63, 3444-6 (1941).
- (5) Bradbury and Linnell, *Quart. J. Pharm. Pharmacol.*, 11, 240-51 (1938).
- (6) Arnold and Liggett, *J. Am. Chem. Soc.*, 64, 2875-7 (1942).
- (7) Arnold and Liggett, *J. Am. Chem. Soc.*, 67, 337-8 (1945).
- (8) Arnold, Liggett, and Searles, *J. Am. Chem. Soc.*, 70, 3938 (1948).
- (9) Arnold and Searles, *J. Am. Chem. Soc.*, 71, 2021-3 (1949).
- (10) Austin and Johnson, *J. Am. Chem. Soc.*, 54, 647-60 (1932).
- (11) Bachman, *J. Am. Chem. Soc.*, 55, 4279-84 (1933).
- (12) Bachman, *Organic Syntheses*, 16, 41-3 (1936); Coll. Vol. II, 323-5 (1943).
- (13) Bachman and Finholt, *J. Am. Chem. Soc.*, 70, 622-4 (1948).
- (14) Bachman and Heisey, *J. Am. Chem. Soc.*, 71, 1985-8 (1949).
- (15) Bachman and Micucci, *J. Am. Chem. Soc.*, 70, 2381-4 (1948).
- (16) Bachmann and Cockerill, *J. Am. Chem. Soc.*, 55, 2932-4 (1933).
- (17) Bachmann and Hetzner, *Organic Syntheses*, 23, 98-100 (1934).
- (18) Backer and Kemper, *Rec. trav. chim.*, 57, 1249-58 (1938).
- (19) Backer, Strating, and Cool, *Rec. trav. chim.*, 58, 778-84 (1939).
- (20) Baeyer, *Ann.*, 354, 152-204 (1907).
- (21) Baeyer, *Ann.*, 372, 80-151 (1910).
- (22) Baker and Squire, *J. Am. Chem. Soc.*, 70, 1487-90 (1948).
- (23) Barbier and Locquin, *Compt. rend.*, 156, 1443-6 (1913); *Chem. Zentr.*, 1913,II, 27; *Chem. Abstr.*, 7, 3110 (1913).
- (24) Barnett and Cook, *J. Chem. Soc.*, 1933, 22-4.
- (25) Barnett, Cook, and Nixon, *J. Chem. Soc.*, 1927, 504-12.
- (26) Barr, Heilbron, and Spring, *J. Chem. Soc.*, 1936, 737-8.
- (27) Barr and Ladouceur, *Can. J. Research*, 27B, 61-6 (1949).
- (28) Barré, *Compt. rend.*, 184, 825-6 (1927).
- (29) Barré, *Ann. chim.*, [10], 9, 204-75 (1927).
- (30) Barrow and Ferguson, *J. Chem. Soc.*, 1935, 410-8.
- (31) Béhal and Sommelet, *Compt. rend.*, 138, 89-92 (1904); *Chem. Zentr.*, 1904,I, 504.
- (32) Béhal and Tiffeneau, *Bull. soc. chim.*, [4], 3, 314-21 (1908).
- (33) Béhal and Tiffeneau, *Bull. soc. chim.*, [4], 3, 732-6 (1908).
- (34) Béhal and Tiffeneau, *Bull. soc. chim.*, [4], 7, 330-2 (1910).
- (35) Berberianu, *Bul. soc. romane stiin.*, 22, 11-25 (1914); *Chem. Abstr.*, 8, 1423 (1914).
- (36) Bergmann, *J. Org. Chem.*, 4, 1-13 (1939).
- (37) Bergmann and Bondi, *J. Am. Chem. Soc.*, 58, 1814 (1936).
- (38) Bergmann and Hartrott, *J. Chem. Soc.*, 1935, 1218-9.
- (39) Bergmann and Israelashvili, *J. Am. Chem. Soc.*, 68, 1-5 (1946).
- (40) Bergmann, Taubadel, and Weiss, *Ber.*, 64B, 1493-501 (1931).
- (41) Bergmann and Weiss, *Ann.*, 480, 64-75 (1930).
- (42) Bert, *Compt. rend.*, 186, 699-700 (1928).
- (43) Bettzieche and Ehrlich, *Z. physiol. Chem.*, 160, 256-62 (1926); *Chem. Abstr.*, 21, 567 (1927).
- (44) Bettzieche and Menger, *Z. physiol. Chem.*, 172, 56-63 (1927); *Chem. Abstr.*, 22, 583 (1928).
- (45) Bettzieche, Menger, and Wolf, *Z. physiol. Chem.*, 160, 270-300 (1926); *Chem. Abstr.*, 21, 568 (1927).

- (46) Billeter and Miescher, *Helv. Chim. Acta*, 31, 1302-18 (1948).
(47) Birch and Robinson, *J. Chem. Soc.*, 1942, 488-97.
(48) Bistrzycki and Gyr, *Ber.*, 37, 1245-53 (1904).
(49) Blaise and Courtot, *Compt. rend.*, 140, 370-2 (1905); *Chem. Zentr.*, 1905, I, 726.
(50) Blicke and Blake, *J. Am. Chem. Soc.*, 53, 1015-25 (1931).
(51) Blicke and Patelski, *J. Am. Chem. Soc.*, 60, 2638-41 (1938).
(52) Blicke and Weinkauff, *J. Am. Chem. Soc.*, 54, 1454-9 (1932).
(53) Blicke and Weinkauff, *J. Am. Chem. Soc.*, 54, 1460-4 (1932).
(54) Blum-Bergmann, *Ann.*, 484, 26-51 (1930).
(55) Bodroux, *Compt. rend.*, 138, 92-4 (1904); *Chem. Zentr.*, 1904, I, 509.
(56) Bodroux, *Compt. rend.*, 138, 700-1 (1904); *Chem. Zentr.*, 1904, I, 1077.
(57) Bodroux, *Bull. soc. chim.*, [3], 31, 585-8 (1904).
(58) Bodroux and Thomassin, *Bull. soc. chim.*, [5], 6, 1411-6 (1939).
(59) Böeseken and Wildschut, *Rec. trav. chim.*, 51, 168-73 (1932).
(60) Bousset and Vaugin, *Bull. soc. chim.*, [4], 47, 986-1003 (1930).
(61) Bouvet, *Bull. soc. chim.*, [4], 17, 202-16 (1915).
(62) Bowden, Harris, and Roberts, *J. Chem. Soc.*, 1939, 302-8.
(63) Boyd and Hatt, *J. Chem. Soc.*, 1927, 898-910.
(64) Boyle, McKenzie, and Mitchell, *Ber.*, 70B, 2153-60 (1937).
(65) Bradsher and Smith, *J. Am. Chem. Soc.*, 65, 1643-5 (1943).
(66) Bruylants, *Bull. acad. roy. Belg.*, 1908, 1011-84; *Chem. Zentr.*, 1909, I, 1859.
(67) Bruylants, *Bull. acad. roy. Belg.*, 1909, 276-82; *Chem. Zentr.*, 1909, II, 797.
(68) Bruylants, *Bull. soc. chim. Belg.*, 33, 529-31 (1924).
(69) Butenandt, Mamoli, and Heusner, *Ber.*, 72B, 1614-7 (1939).
(70) Butenandt and Schmidt-Thomé, *Ber.*, 72B, 182-7 (1939).
(71) Buu-Hoï, *Ann. chim.*, [11], 19, 446-58 (1944).
(72) Buu-Hoï and Janicaud, *Bull. soc. chim.*, [5], 13, 147-8 (1946).
(73) Cagniant and Deluzarche, *Compt. rend.*, 224, 473-4 (1947); *Chem. Abstr.*, 41, 5100 (1947).
(74) Calingaert and Soroos, *J. Am. Chem. Soc.*, 58, 635-6 (1936).
(75) Campbell and Campbell, *J. Am. Chem. Soc.*, 60, 1372-6 (1938).
(76) Carothers and Hill, *J. Am. Chem. Soc.*, 54, 1588-90 (1932).
(77) Cason, Adams, Bennett, and Register, *J. Am. Chem. Soc.*, 66, 1764-7 (1944).
(78) Chatterjee, Bose, and Roy, *J. Indian Chem. Soc.*, 24, 169-72 (1947); *Chem. Abstr.*, 43, 2613 (1949).
(79) Chonin, *J. Russ. Phys.-Chem. Soc.*, 41, 327-44 (1909); *Chem. Zentr.*, 1909, II, 587.
(80) Church, Whitmore, and McGrew, *J. Am. Chem. Soc.*, 56, 176-84 (1934).
(81) Clarkson and Gomberg, *J. Am. Chem. Soc.*, 52, 2881-91 (1930).
(82) Clément, *Compt. rend.*, 198, 665-7 (1937).
(83) Clément, *Compt. rend.*, 202, 425-7 (1936); *Chem. Abstr.*, 30, 2932 (1936).
(84) Clément, *Compt. rend.*, 207, 864-6 (1938); *Chem. Abstr.*, 33, 7747 (1939).
(85) Clément, *Ann. chim.*, [11], 13, 243-316 (1940).
(86) Coleman and Craig, *Organic Syntheses*, 15, 11-3 (1935); *Coll. Vol. II*, 179-81 (1943).
(87) Conant and Blatt, *J. Am. Chem. Soc.*, 51, 1227-36 (1929).
(88) Cook, *J. Chem. Soc.*, 1932, 456-72.
(89) Courtot, *Bull. soc. chim.*, [3], 35, 969-88 (1906).
(90) Couturier, *Compt. rend.*, 202, 1994-6 (1936); *Chem. Abstr.*, 30, 6725 (1936).
(91) Dalebroux and Wuyts, *Bull. soc. chim. Belg.*, 20, 156-8 (1906).
(92) Dalmer, von Werder, Honigmann, and Heyns, *Ber.*, 68B, 1814-25 (1935).
(93) Darzens and Levy, *Compt. rend.*, 201, 152-4 (1935); *Chem. Abstr.*, 29, 6593 (1935).

- (94) Davies and Kipping, *J. Chem. Soc.*, 99, 296-301 (1911).
(95) Dillon and Lucas, *J. Am. Chem. Soc.*, 50, 1711-4 (1928).
(96) Diltthey and Last, *Ber.*, 37, 2639-41 (1904).
(97) Dirstine and Bergstrom, *J. Org. Chem.*, 11, 55-9 (1946).
(98) Dornfeld and Coleman, *Organic Syntheses*, 28, 83-7 (1948).
(99) Dow Chemical Co., British Patent 618,638, Feb. 24, 1949; *Chem. Abstr.*, 43, P5806 (1949).
(100) Dufraisse and Monier, *Compt. rend.*, 196, 1325-9 (1933); *Chem. Abstr.*, 27, 3471 (1933).
(101) Edgar, Calingaert, and Marker, *J. Am. Chem. Soc.*, 51, 1483-91 (1929).
(102) Egorowa, *J. Russ. Phys.-Chem. Soc.*, 41, 1454-68 (1909); *Chem. Zentr.*, 1910,I, 1003.
(103) Feist, Awe, Kuklinski, and Völksen, *Arch. Pharm.*, 276, 271-9 (1938); *Chem. Abstr.*, 32, 6651 (1938).
(104) Fieser and Hershberg, *J. Am. Chem. Soc.*, 59, 2331-5 (1937).
(105) Fieser and Heymann, *J. Am. Chem. Soc.*, 64, 376-82 (1942).
(106) Fieser and Newman, *J. Am. Chem. Soc.*, 58, 2376-82 (1936).
(107) Fischer, Baumgartner, and Plotz, *Ann.*, 493, 1-19 (1932).
(108) Fischer and Hess, *Ber.*, 45, 912-5 (1912).
(109) Földi and Demjén, *Ber.*, 74B, 930-4 (1941).
(110) Fourneau and Tiffeneau, *Compt. rend.*, 145, 437-9 (1907); *Chem. Zentr.*, 1907,II, 1320.
(111) Fourneau, Tréfouel, Tréfouel, and Benoit, *Ann. inst. Pasteur*, 44, 719-51 (1930); *Chem. Abstr.*, 26, 1592 (1932).
(112) Frank, Arvan, Richter, and Vannemann, *J. Am. Chem. Soc.*, 66, 4-6 (1944).
(113) Frankland and Twiss, *J. Chem. Soc.*, 85, 1666-7 (1904).
(114) French and Smith, *J. Am. Chem. Soc.*, 67, 1949-50 (1945).
(115) Friedr. Bayer & Co., German Patent 157,573, Nov. 28, 1904; *Friedländer*, 8, 156-7 (1905-7).
(116) Fröschl, Zellner, and Zak, *Monatsb.*, 55, 25-46 (1930).
(117) Frostick, Baumgarten, and Hauser, *J. Am. Chem. Soc.*, 66, 305 (1944).
(118) Frumina, *Bull. acad. roy. Belg.*, 1909, 1151-7; *Chem. Zentr.*, 1910,I, 1001.
(119) Fuson, Bottorff, Foster, and Speck, *J. Am. Chem. Soc.*, 64, 2573-6 (1942).
(120) Fuson, Bottorff, and Speck, *J. Am. Chem. Soc.*, 64, 1450-3 (1942).
(121) Fuson and Rachlin, *J. Am. Chem. Soc.*, 64, 1567-71 (1942).
(122) Fuson and Ward, *J. Am. Chem. Soc.*, 68, 521-2 (1946).
(123) Gakhokidze, *J. Gen. Chem. (U.S.S.R.)*, 11, 109-16 (1941); *Chem. Abstr.*, 35, 5464 (1941).
(124) Gattermann, *Ann.*, 393, 215-34 (1912).
(125) Gattermann and Maffezzoli, *Ber.*, 36, 4152-3 (1903).
(126) Gillespie and Marvell, *J. Am. Chem. Soc.*, 52, 3368-76 (1930).
(127) Gilman and Franz, *Rec. trav. chim.*, 51, 991-5 (1932).
(128) Godchot and Cauquil, *Compt. rend.*, 200, 1479-81 (1935); *Chem. Abstr.*, 29, 7940 (1935).
(129) Godnew, *Ber.*, 68B, 422-3 (1935).
(130) Golovchanskaya, *J. Gen. Chem. (U.S.S.R.)*, 16, 1243-7 (1946); *Chem. Abstr.*, 41, 3082 (1947).
(131) Gomberg and Van Slyke, *J. Am. Chem. Soc.*, 33, 531-49 (1911).
(132) Graf, *J. prakt. Chem.*, [2], 146, 88-104 (1936).
(133) Grard, *Compt. rend.*, 189, 541-3 (1929).
(134) Greenwood and Gortner, *J. Org. Chem.*, 6, 401-9 (1941).
(135) Grignard, *Compt. rend.*, 132, 336-8 (1901); *Chem. Zentr.*, 1901,I, 612.
(136) Grignard, *Ann. Univ. Lyon, N.S.*, 6, 1-116 (1901); *Chem. Zentr.*, 1901,II, 622.
(137) Grignard, *Compt. rend.*, 134, 849-51 (1902); *Chem. Zentr.*, 1902,I, 1197.

- (138) Grignard, *Compt. rend.*, 135, 627-30 (1902); *Chem. Zentr.*, 1902,II, 1359.
(139) Grignard, *Ann. chim.*, [7], 27, 548-74 (1902).
(140) Grignard and Vignon, *Compt. rend.*, 144, 1358-60 (1907); *Chem. Zentr.*, 1907,II, 681.
(141) Gripenberg and Lindahl, *Acta Chem. Scand.*, 3, 256-8 (1949); *Chem. Abstr.*, 43, 7928 (1949).
(142) Grishkevich-Trokhimovskii, *J. Russ. Phys.-Chem. Soc.*, 43, 204-7 (1912); *Chem. Abstr.*, 6, 223 (1912).
(143) Grishkevich-Trokhimovskii, *J. Russ. Phys.-Chem. Soc.*, 43, 803-6 (1912); *Chem. Abstr.*, 6, 477 (1912).
(144) Guillaumin, *Bull. soc. chim.*, [4], 7, 374-83 (1910).
(145) Guyot and Catel, *Compt. rend.*, 140, 254-6 (1905); *Chem. Zentr.*, 1905,I, 679.
(146) Guyot and Catel, *Bull. soc. chim.*, [3], 35, 551-62 (1906).
(147) Hale, McNally, and Pater, *Am. Chem. J.*, 35, 67-78 (1906);
(148) Haller and Guyot, *Bull. soc. chim.*, [3], 31, 979-85 (1904).
(149) Halse, *J. prakt. Chem.*, [2], 89, 451-65 (1914).
(150) Hamel, *Bull. soc. chim.*, [4], 29, 390-402 (1921).
(151) Harries and Turk, *Ann.*, 343, 360-9 (1905).
(152) Harries and Weil, *Ann.*, 343, 362-9 (1905).
(153) Hauser, Saperstein, and Shivers, *J. Am. Chem. Soc.*, 70, 606-8 (1948).
(154) Hauser, Yost, and Ringler, *J. Org. Chem.*, 14, 261-71 (1949).
(155) Hell and Schaal, *Ber.*, 40, 4162-6 (1907).
(156) Hennion and Raley, *J. Am. Chem. Soc.*, 70, 865-6 (1948).
(157) Henry, *Compt. rend.*, 142, 1023-4 (1906); *Chem. Zentr.*, 1906,II, 15.
(158) Henry, *Compt. rend.*, 143, 1221-5 (1906); *Chem. Zentr.*, 1907,I, 708.
(159) Henry, *Compt. rend.*, 144, 308-13 (1907); *Chem. Zentr.*, 1907,I, 1102.
(160) Henry, *Bull. soc. chim. Belg.*, 20, 152-6 (1906).
(161) Henry and Dewael, *Bull. acad. roy. Belg., Classe sci.*, 1908, 857-63; *Chem. Zentr.*, 1909,I, 1854.
(162) Henze, Allen, and Leslie, *J. Org. Chem.*, 7, 326-35 (1942).
(163) Hepworth, *J. Chem. Soc.*, 115, 1203-10 (1919).
(164) Hey and Carter, British Patent 586,493, March 20, 1947; *Chem. Abstr.*, 42, P1967 (1948).
(165) Hoehn and Mason, *J. Am. Chem. Soc.*, 60, 1493-7 (1938).
(166) Houben, *Ber.*, 36, 3087-9 (1903).
(167) Howell, *J. Am. Chem. Soc.*, 42, 2333-7 (1920).
(168) Hudson, *J. Chem. Soc.*, 1946, 76-8.
(169) Hurd and Bonner, *J. Am. Chem. Soc.*, 67, 1972-7 (1945).
(170) Hurd, Jones, and Blunck, *J. Am. Chem. Soc.*, 57, 2033-6 (1935).
(171) Huston, Jackson, and Spero, *J. Am. Chem. Soc.*, 63, 1459-60 (1941).
(172) Ingraffia, *Gazz. chim. ital.*, 63, 584-91 (1933); *Chem. Abstr.*, 28, 1342 (1934).
(173) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 35, 1269-75 (1905); *Bull. soc. chim.*, [3], 34, 181 (1905).
(174) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 35, 553-4 (1903); *Bull. soc. chim.*, [3], 32, 719 (1904).
(175) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 36, 1551-3 (1904); *Bull. soc. chim.*, [3], 36, 179 (1906).
(176) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 42, 1490-1 (1910); *Bull. soc. chim.*, [4], 10, 1294 (1911);
(177) Iotsitch, Breitfous, Roudolf, Stassevitch, Kondyref, and Fomine, *J. Russ. Phys.-Chem. Soc.*, 39, 652-7 (1907); *Bull. soc. chim.*, [4], 6, 98 (1909).
(178) Iotsitch and Lebedef, *J. Russ. Phys.-Chem. Soc.*, 42, 1494-5 (1910); *Bull. soc. chim.*, [4], 10, 1294 (1911).

- (179) Iotsitch and Lebedef, *J. Russ. Phys.-Chem. Soc.*, 42, 1495 (1910); *Bull. soc. chim.*, [4], 10, 1294 (1911).
- (180) Isihara, *J. Biochem. (Japan)*, 27, 265-77 (1938); *Chem. Abstr.*, 33, 4265 (1939).
- (181) Ivanoff, *Compt. rend.*, 193, 773-6 (1931); *Chem. Abstr.*, 26, 963 (1932).
- (182) Ivanov and Ivanov, *Ber.*, 77B, 180-5 (1944).
- (183) Ivanoff and Spassoff, *Bull. soc. chim.*, [4], 49, 375-7 (1931).
- (184) Ivanoff and Spassoff, *Bull. soc. chim.*, [5], 2, 816-24 (1935).
- (185) Johnston and Quayle, *J. Am. Chem. Soc.*, 70, 479-82 (1948).
- (186) Julian, Cole, and Diemer, *J. Am. Chem. Soc.*, 67, 1721-3 (1945).
- (187) Julian, Cole, and Meyer, *J. Am. Chem. Soc.*, 67, 1724-7 (1945).
- (188) Kanao and Inagawa, *J. Pharm. Soc., Japan*, 48, 66-8 (1928); *Chem. Zentr.*, 1928,II, 50.
- (189) Kanao and Inagawa, *J. Pharm. Soc. Japan*, 48, 238-52 (1928); *Chem. Abstr.*, 22, 2923 (1928).
- (190) Kanao and Shinozuka, *J. Pharm. Soc. Japan*, 50, 148-52 (1930); *Chem. Zentr.*, 1931,I, 1743.
- (191) Kanao and Yaguchi, *J. Pharm. Soc. Japan*, 48, 252-8 (1928); *Chem. Zentr.*, 1928,II, 51; *Chem. Abstr.*, 22, 2937 (1928).
- (192) Kanao and Yaguchi, *J. Pharm. Soc. Japan*, 48, 358-66 (1928); *Chem. Zentr.*, 1928,II, 52; *Chem. Abstr.*, 22, 3407 (1928).
- (193) Kapfhammer and Matthes, *Z. physiol. Chem.*, 223, 43-52 (1933); *Chem. Abstr.*, 28, 2353 (1934); *Chem. Zentr.*, 1934,I, 2759.
- (194) Karasev, *J. Gen. Chem. (U.S.S.R.)*, 7, 179-84 (1937); *Chem. Abstr.*, 31, 4268 (1937).
- (195) Karrer and Rubel, *Helv. Chim. Acta*, 17, 773-4 (1934).
- (196) Karvonen, *Suomen Kemistilehti*, 3, 101-11 (1930); *Chem. Zentr.*, 1931,I, 3344.
- (197) Kauffmann and Egner, *Ber.*, 46, 3779-88 (1913).
- (198) Kauffmann and Kieser, *Ber.*, 45, 2333-7 (1912).
- (199) Kauffmann and Kieser, *Ber.*, 46, 3788-801 (1913).
- (200) Kharasch and Clapp, *J. Org. Chem.*, 3, 355-60 (1938).
- (201) Kirrmann, *Ann. chim.*, [10], 11, 223-86 (1929).
- (202) Kishner and Amosow, *J. Russ. Phys.-Chem. Soc.*, 37, 517-20 (1905); *Chem. Zentr.*, 1905,II, 816.
- (203) Kislovskaya, *J. Russ. Phys.-Chem. Soc.*, 45, 1975-9 (1914); *Chem. Abstr.*, 8, 1421 (1914).
- (204) Klages, *Ber.*, 37, 1721-6 (1904).
- (205) Klages and Heilmann, *Ber.*, 37, 1447-57 (1904).
- (206) Kliegl, *Ber.*, 38, 84-7 (1905).
- (207) Kling, *Bull. soc. chim.*, [3], 31, 16-9 (1904).
- (208) Koelsch, *J. Am. Chem. Soc.*, 58, 1331-3 (1935).
- (209) Koelsch, *J. Am. Chem. Soc.*, 65, 1639-40 (1943).
- (210) Koelsch and Johnson, *J. Am. Chem. Soc.*, 65, 565-7 (1943).
- (211) Kohler, *Am. Chem. J.*, 31, 642-61 (1904).
- (212) Kohler, *Am. Chem. J.*, 34, 132-47 (1906).
- (213) Kohler, *Am. Chem. J.*, 36, 529-38 (1906).
- (214) Kohler and Butler, *J. Am. Chem. Soc.*, 48, 1036-48 (1926).
- (215) Kohler and Conant, *J. Am. Chem. Soc.*, 39, 1699-715 (1917).
- (216) Kohler and Heritage, *Am. Chem. J.*, 33, 21-35 (1905).
- (217) Kohler and Heritage, *Am. Chem. J.*, 33, 153-64 (1905).
- (218) Kohler and Heritage, *Am. Chem. J.*, 34, 568-80 (1906).
- (219) Kohler and Johnstin, *Am. Chem. J.*, 33, 35-45 (1905).
- (220) Kohler and Reimer, *Am. Chem. J.*, 33, 333-56 (1905).

- (221) Kohler, Richtmyer, and Hester, *J. Am. Chem. Soc.*, 53, 205-21 (1931).
(222) Kovache, *Ann. chim.*, [9], 10, 184-248 (1918).
(223) Kritchevsky, *J. Am. Chem. Soc.*, 65, 487 (1943).
(224) LaGrave, *Ann. chim.*, [10], 8, 363-446 (1927).
(225) Lammer, *Monatsh.*, 35, 171-88 (1914).
(226) Landa, Cech, and Sliva, *Collection Czechoslov. Chem. Commun.*, 5, 204-10 (1933); *Chem. Abstr.*, 27, 4211 (1933).
(227) Landa and Habada, *Collection Czechoslov. Chem. Commun.*, 8, 473-6 (1936); *Chem. Abstr.*, 31, 1757 (1937).
(228) Landa and Kejvan, *Collection Czechoslov. Chem. Commun.*, 3, 367-76 (1931); *Chem. Abstr.*, 26, 77 (1932).
(229) Landa and Riedl, *Collection Czechoslov. Chem. Commun.*, 2, 520-30 (1930); *Chem. Zentr.*, 1931,1, 2454; *Chem. Abstr.*, 25, 67 (1931).
(230) Landa and Sliva, *Collection Czechoslov. Chem. Commun.*, 4, 538-42 (1932); *Chem. Abstr.*, 27, 1611 (1933).
(231) Lapkin, *J. Gen. Chem. (U.S.S.R.)*, 16, 721-8 (1936); *Chem. Abstr.*, 41, 1218 (1947).
(232) Lapkin, *J. Gen. Chem. (U.S.S.R.)*, 16, 729-34 (1946); *Chem. Abstr.*, 41, 1218 (1947).
(233) Lapkin, *J. Gen. Chem. (U.S.S.R.)*, 17, 1339-50 (1947); *Chem. Abstr.*, 42, 4978 (1948).
(234) Lapkin and Lyubimova, *J. Gen. Chem. (U.S.S.R.)*, 18, 701-9 (1948); *Chem. Abstr.*, 43, 188 (1949).
(235) Lapkin, Shklyayev, and Shklyayeva, *J. Gen. Chem. (U.S.S.R.)*, 10, 1449-52 (1940); *Chem. Abstr.*, 35, 2479 (1941).
(236) Lapkin, Shklyayeva, Koryakina, and Vinokurova, *J. Gen. Chem. (U.S.S.R.)*, 17, 1332-8 (1947); *Chem. Abstr.*, 42, 4978 (1948).
(237) Lemaire, *Bull. acad. roy. Belg.*, 1909, 83-159; *Rec. trav. chim.*, 29, 22-84 (1910); *Chem. Zentr.*, 1909,1, 1982; *Chem. Abstr.*, 4, 1483 (1910).
(238) Leroide, *Ann. chim.*, [9], 16, 354-410 (1921).
(239) Lespieau, *Bull. soc. chim.*, [5], 6, 947-9 (1939).
(240) Letellier, *Compt. rend.*, 146, 343-5 (1908); *Chem. Zentr.*, 1908,1, 1378.
(241) Levene and Marker, *J. Biol. Chem.*, 95, 1-24 (1932).
(242) Levene and Marker, *J. Biol. Chem.*, 100, 769-73 (1933).
(243) Levene and Marker, *J. Biol. Chem.*, 101, 413-8 (1933).
(244) Lévy and Pernot, *Bull. soc. chim.*, [4], 49, 1721-30 (1931).
(245) Liang, *Bull. soc. chim.*, [4], 53, 33-41 (1933).
(246) Loder and Whitmore, *J. Am. Chem. Soc.*, 57, 2727 (1935).
(247) Long, Marshall, and Gallagher, *J. Biol. Chem.*, 165, 197-209 (1946).
(248) Lund, *J. Am. Chem. Soc.*, 49, 1346-60 (1927).
(249) Lüttringhaus and Sholtis, *Ann.*, 557, 70-82 (1945).
(250) MacLeod, *Am. Chem. J.*, 44, 331-52 (1910).
(251) Malengreau, *Bull. acad. roy. Belg., Classe sci.*, 1906, 802-10; *Chem. Zentr.*, 1907,1, 1398; *Chem. Abstr.*, 1, 1970 (1907).
(252) Maman, *Compt. rend.*, 198, 1323-5 (1934).
(253) Marker, Kamm, Jones, Wittle, Oakwood, and Crooks, *J. Am. Chem. Soc.*, 59, 768 (1937).
(254) Marker, Kamm, McGinty, Jones, Wittle, Oakwood, and Crooks, *J. Am. Chem. Soc.*, 59, 1367-8 (1937).
(255) Marvel, Dietz, and Himel, *J. Org. Chem.*, 7, 392-6 (1942).
(256) Marvel, Ginsberg, and Mueller, *J. Am. Chem. Soc.*, 61, 77-8 (1939).
(257) Marvel, Kaplan, and Himel, *J. Am. Chem. Soc.*, 63, 1892-6 (1941).
(258) Moyer and Marvel, *Organic Syntheses*, 11, 98-100 (1931); Coll. Vol. II, 602-4 (1943).

- (259) Masson, *Compt. rend.*, 132, 483-5 (1901); *Chem. Zentr.*, 1901,1, 725.
(260) Masson, *Compt. rend.*, 135, 533-4 (1902); *J. Chem. Soc.*, 84,1, 28 (1903).
(261) Mavrodin, *Compt. rend.*, 183, 1504-6 (1929).
(262) Mavrodin, *Compt. rend.*, 191, 1064-6 (1930).
(263) Mavrodin, *Compt. rend.*, 192, 363-5 (1931).
(264) Maxim and Georgescu, *Bull. soc. chim.*, [5], 3, 1114-24 (1936).
(265) Maxim and Stancovici, *Bull. soc. chim.*, [5], 3, 1319-23 (1936).
(266) May and Mosettig, *J. Org. Chem.*, 13, 459-64 (1948).
(267) Mazurewitsch, *J. Russ. Phys.-Chem. Soc.*, 42, 1582-9 (1910); *Chem. Zentr.*, 1911,1, 1500.
(268) McKenzie and Duff, *Ber.*, 60B, 1335-41 (1927).
(269) McKenzie and Lesslie, *Ber.*, 62B, 288-95 (1929).
(270) McKenzie, Martin, and Rule, *J. Chem. Soc.*, 105, 1583-91 (1914).
(271) McKenzie and Mills, *Ber.*, 62B, 284-8 (1929).
(272) McKenzie, Mills, and Myles, *Ber.*, 63B, 904-11 (1930).
(273) McKenzie and Richardson, *J. Chem. Soc.*, 123, 79-91 (1923).
(274) McKenzie, Roger, and Wills, *J. Chem. Soc.*, 1926, 779-91.
(275) McKenzie and Wills, *J. Chem. Soc.*, 127, 283-95 (1925).
(276) McKenzie and Winton, *J. Chem. Soc.*, 1940, 840-4.
(278) McKenzie and Wren, *J. Chem. Soc.*, 97, 473-86 (1910).
(279) McPhee and Ball, *J. Am. Chem. Soc.*, 66, 1636-50 (1944).
(280) Meerwein, *Ann.*, 396, 200-63 (1913).
(281) Meerwein, *Ann.*, 419, 121-75 (1919).
(282) Meerwein and Unkel, *Ann.*, 376, 152-63 (1910).
(283) Messer, *Chem. News*, 138, 292-3 (1929).
(284) Michiels, *Bull. soc. chim. Belg.*, 27, 25-6 (1913).
(285) Midzuch, *J. Gen. Chem. (U.S.S.R.)*, 16, 147-4 (1946); *Chem. Abstr.*, 41, 5508 (1947).
(286) Mikhailov and Blokhina, *J. Gen. Chem. (U.S.S.R.)*, 13, 609-15 (1943); *Chem. Abstr.*, 39, 702 (1945).
(287) Miller and Bachman, *J. Am. Chem. Soc.*, 57, 766-71 (1935).
(288) Mills and Dazeley, *J. Chem. Soc.*, 1939, 460-3.
(289) Moffett, Stafford, Linsk, and Hoehn, *J. Am. Chem. Soc.*, 68, 1857-60 (1946).
(290) Morsman, Steiger, and Reichstein, *Helv. Chim. Acta*, 20, 3-16 (1937).
(291) Morton and Peakes, *J. Am. Chem. Soc.*, 55, 2110-2 (1933).
(292) Moskalenko, *J. Russ. Phys.-Chem. Soc.*, 44, 1862-5 (1912); *Chem. Zentr.*, 1913,1, 1408.
(293) Mothwurf, *Ber.*, 37, 3153-63 (1904).
(294) Moureu and Barrett, *Bull. soc. chim.*, [4], 29, 993-1006 (1921).
(295) Mousseron and Granger, *Compt. rend.*, 217, 483-5 (1943); *Chem. Abstr.*, 39, 2066 (1945).
(296) Mousseron and Granger, *Bull. soc. chim.*, [5], 13, 251-6 (1946).
(297) Mousseron and Jacquier, *Compt. rend.*, 226, 256-8 (1948); *Chem. Abstr.*, 42, 3734 (1948).
(298) Muset, *Bull. acad. roy. Belg., Classe sci.*, 1906, 775-89; *Chem. Abstr.*, 1, 1969 (1907).
(299) Nametkin and Gabriadze, *J. Gen. Chem. (U.S.S.R.)*, 13, 560-8 (1943); *Chem. Abstr.*, 39, 1142 (1945).
(300) Nametkin and Volodina, *J. Gen. Chem. (U.S.S.R.)*, 17, 325-34 (1947); *Chem. Abstr.*, 42, 527 (1948).
(301) Naylor, *J. Chem. Soc.*, 1947, 1106-8.
(302) Nazarov and Elizarova, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1940, 189-94; *Chem. Abstr.*, 36, 741 (1942).
(303) Neunhoeffter, *Ann.*, 509, 115-30 (1934).

- (304) Neunhoefffer, *Ann.*, 526, 58-65 (1936).
(305) Neunhoefffer and Nerdel, *Ann.*, 526, 47-58 (1936).
(306) Neunhoefffer and Schluter, *Ann.*, 526, 65-71 (1936).
(307) Norris and Cortese, *J. Am. Chem. Soc.*, 49, 2640-50 (1927).
(308) Ochiai and Ichikawa, *J. Pharm. Soc. Japan*, 58, 632-6 (1938); *Chem. Abstr.*, 32, 8427 (1938).
(309) Oparin, *J. Russ. Phys.-Chem. Soc.*, 61, 2011-5 (1929); *Chem. Zentr.*, 1930, 1, 3556; *Chem. Abstr.*, 24, 4785 (1930).
(310) Orechhoff and Konowaloff, *Ber.*, 45, 861-5 (1912).
(311) Orékhoff, *Bull. soc. chim.*, [4], 25, 108-11 (1919).
(312) Orékhoff, *Bull. soc. chim.*, [4], 25, 111-5 (1919).
(313) Organon, British Patent 495,156, Nov. 8, 1938; *Chem. Abstr.*, 33, P2534 (1939).
(314) Paal, *Ber.*, 49, 1583-97 (1916).
(315) Paal and Hornstein, *Ber.*, 39, 1361-4 (1906).
(316) Paal and Kinscher, *Ber.*, 44, 1343-55 (1911).
(317) Paal and Weidenkaff, *Ber.*, 38, 1686-91 (1905).
(318) Paal and Weidenkaff, *Ber.*, 39, 810-3 (1906).
(319) Paal and Weidenkaff, *Ber.*, 39, 2062-3 (1906).
(320) Paal and Weidenkaff, *Ber.*, 39, 4344-6 (1906).
(321) Paal and Zahn, *Ber.*, 40, 1819-21 (1907).
(322) Paloma, *Ber.*, 42, 1299-302 (1909).
(323) Paloma and Kaski, *Ber.*, 72B, 317-8 (1939).
(324) Paloma and Kaski, *Suomen Kemistilehti*, 17B, 7-9 (1944); *Chem. Abstr.*, 40, 6414 (1946).
(325) Pearlman, *J. Am. Chem. Soc.*, 69, 1475-6 (1947).
(326) Pétróff, Karasseff, and Tschelzowa, *Compt. rend. acad. sci. U.R.S.S.*, [N.S.], 4, 31-5 (1935); *Bull. soc. chim.*, [5], 3, 169-76 (1936); *Chem. Abstr.*, 30, 2915 (1936).
(327) Petrov, *Sci. Records Gorky State Univ.*, 7, 3-9 (1939); *Chem. Abstr.*, 35, 435 (1941).
(328) Petrov, *Doklady Akad. Nauk S.S.S.R.*, 63, 41-4 (1948); *Chem. Abstr.*, 43, 2604 (1949).
(329) Petrov, Belyaeva, and Kukanova, *Sci. Records Gorky State Univ.*, No. 7, 14-6 (1939); *Khim. Referat. Zhur.*, 1940, No. 10-11, 20; *Chem. Abstr.*, 37, 1379 (1943).
(330) Petrov and Chel'tsova, *J. Gen. Chem. (U.S.S.R.)*, 12, 87-94 (1942); *Chem. Abstr.*, 37, 1993 (1943).
(331) Petrov and Kaplan, *Doklady Akad. Nauk S.S.S.R.*, 64, 683-5 (1949); *Chem. Abstr.*, 43, 5368 (1949).
(332) Petrov, Koptev, and Kaplan, *Bull. acad. sci. U.R.S.S., Classe. sci. chim.*, 1944, 152-5; *Chem. Abstr.*, 39, 1617 (1945).
(333) Petrov and Kurbskiĭ, *J. Gen. Chem. (U.S.S.R.)*, 14, 492-4 (1944); *Chem. Abstr.*, 39, 4600 (1945).
(334) Petrov, Lapteva, and Pchelkina, *J. Gen. Chem. (U.S.S.R.)*, 14, 495-7 (1944); *Chem. Abstr.*, 39, 4598 (1945).
(335) Petrov and Malinovskiĭ, *Sci. Records Gorky State Univ.*, No. 7, 9-14 (1939); *Khim. Referat. Zhur.*, 1940, No. 10-11, 20; *Chem. Abstr.*, 37, 1378 (1943).
(336) Petrov and Sanin, *J. Gen. Chem. (U.S.S.R.)*, 8, 195-8 (1938); *Chem. Abstr.*, 32, 5376 (1938).
(337) Petrov and Sanin, *J. Gen. Chem. (U.S.S.R.)*, 9, 2129-37 (1939); *Chem. Abstr.*, 34, 4054 (1940).
(338) Petrov and Sokolova, *J. Gen. Chem. (U.S.S.R.)*, 8, 199-206 (1938); *Chem. Abstr.*, 32, 5376 (1938).

- (339) Petrov and Vittikh, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1944, 152-5; *Chem. Abstr.*, 39, 1618 (1945).
- (340) Petyunin, *Trudy Moskov. Med. Inst.*, 1940, No. 16, 7-12; *Khim. Referat. Zhur.*, 4, No. 9, 58 (1941); *Chem. Abstr.*, 38, 950 (1944).
- (341) Petyunin, *Trudy Molotov. Med. Inst.*, 1940, No. 16, 13-16; *Khim. Referat. Zhur.*, 4, No. 9, 58 (1941); *Chem. Abstr.*, 38, 2636 (1944).
- (342) Pogorjelsky, *J. Russ. Phys.-Chem. Soc.*, 35, 882-96 (1904); *Chem. Zentr.*, 1904,I, 578.
- (343) Preisseecker, *Monatsh*, 35, 889-908 (1914).
- (344) Proost and Wibaut, *Rec. trav. chim.*, 59, 971-7 (1940).
- (345) Purdie and Arup, *J. Chem. Soc.*, 97, 1524-36 (1910).
- (346) Purdie and Arup, *J. Chem. Soc.*, 97, 1537-46 (1910).
- (347) Purdie and Young, *J. Chem. Soc.*, 97, 1524-36 (1910).
- (348) Putochin, *Ber.*, 59B, 1987-98 (1926).
- (349) Quelet, *Bull. soc. chim.*, [4], 45, 255-74 (1929).
- (350) Quilico and Freri, *Gazz. chim. ital.*, 76, 87-107 (1946); *Chem. Abstr.*, 41, 383 (1947).
- (351) Reichstein and von Artz, *Helv. Chim. Acta*, 23, 747-53 (1940).
- (352) Reimer, *Am. Chem. J.*, 38, 227-37 (1907).
- (353) Reimer and Reynolds, *Am. Chem. J.*, 40, 428-44 (1908).
- (354) Reindel and Niederlander, *Ber.*, 68B, 1969-73 (1935).
- (355) Remfrey and Decker, *Ber.*, 41, 1007-9 (1908).
- (356) Reynolds, *Am. Chem. J.*, 44, 305-31 (1910).
- (357) Reynolds, *Am. Chem. J.*, 46, 198-211 (1911).
- (358) Riegel, Dunker, and Thomas, *J. Am. Chem. Soc.*, 64, 2115-20 (1942).
- (359) Riegel and Meyer, *J. Am. Chem. Soc.*, 68, 1097-9 (1946).
- (360) Riegel, Siegel, and Lilienfeld, *J. Am. Chem. Soc.*, 68, 984-5 (1946).
- (361) Rivière, *Ann. chim.*, [12], 1, 157-231 (1946).
- (362) Roger and McKay, *J. Chem. Soc.*, 1931, 2229-38.
- (363) Rubin, Kozłowski, and Salmon, *J. Am. Chem. Soc.*, 67, 192-3 (1945).
- (364) Sachs and Loevy, *Ber.*, 36, 3236 (1903).
- (365) Sah, *J. Am. Chem. Soc.*, 64, 1487-8 (1942).
- (366) Sah, *J. Chinese Chem. Soc.*, 13, 89-95 (1946); *Chem. Abstr.*, 41, 5869 (1947).
- (367) Salmon and Rubin, U. S. Patent 2,393,570, Jan. 22, 1946; *Chem. Abstr.*, 40, P3572 (1946).
- (368) Savard and Hösöğüt, *Rev. faculté sci. univ. Istanbul*, [N.S.], 3, 164-73 (1938); *Chem. Abstr.*, 32, 5795 (1938).
- (369) Scheibler and Schmidt, *Ber.*, 67B, 1514-8 (1934).
- (370) Schlenk and Brauns, *Ber.*, 48, 716-28 (1915).
- (371) Schlenk and Ochs, *Ber.*, 48, 676-80 (1915).
- (372) Schlenk and Weickel, *Ann.*, 368, 295-304 (1909).
- (373) Schmidlin, *Ber.*, 43, 1137-44 (1910).
- (374) Schmidlin and Huber, *Ber.*, 43, 2824-37 (1910).
- (375) Schmidlin and Massini, *Ber.*, 42, 2377-92 (1909).
- (376) Schmidlin and von Escher, *Ber.*, 41, 447-50 (1908).
- (377) Schmidt and Hartmann, *Ber.*, 74B, 1325-32 (1941).
- (378) Schorigin, *Ber.*, 40, 3111-8 (1907).
- (379) Schreiner, *J. prakt. Chem.*, [2], 82, 292-6 (1910).
- (380) Sen and Sidhu, *J. Indian Chem. Soc.*, 25, 433-6 (1948); *Chem. Abstr.*, 43, 4674 (1949).
- (381) Shamshurin, *J. Gen. Chem. (U.S.S.R.)*, 13, 569-72 (1943); *Chem. Abstr.*, 39, 700 (1945).
- (382) Shibata, *J. Chem. Soc.*, 95, 1449-56 (1909).

- (383) Shine and Turner, *Nature*, 158, 170 (1946).
(384) Shivers, Hudson, and Hauser, *J. Am. Chem. Soc.*, 65, 2051-3 (1943).
(385) Ghosh, *Science and Culture*, 3, 120-1 (1937); *Chem. Abstr.*, 32, 145 (1938).
(386) Simon, Kaufmann, and Schinz, *Helv. Chim. Acta*, 29, 1133-44 (1946).
(387) Slavjanov, *J. Russ. Phys.-Chem. Soc.*, 39, 140-60 (1907); *Chem. Abstr.*, 1, 2077 (1907).
(388) Smith, *J. Chem. Soc.*, 1946, 572-3.
(389) Smith and Bayliss, *J. Org. Chem.*, 6, 437-42 (1941).
(390) Smith and Hoehn, *J. Am. Chem. Soc.*, 63, 1176-8 (1941).
(391) Smith and Nichols, *J. Org. Chem.*, 6, 489-506 (1941).
(392) Sobiecki, *Ber.*, 41, 4103-10 (1908).
(393) Sommelet and Hamel, *Bull. soc. chim.*, [4], 29, 545-53 (1921).
(394) Sorkin and Reichstein, *Helv. Chim. Acta*, 28, 875-91 (1945).
(395) Speck and Bost, *J. Org. Chem.*, 11, 788-94 (1946).
(396) Spielman and Schmidt, *J. Am. Chem. Soc.*, 59, 2009-10 (1937).
(397) Ssergejew, *J. Russ. Phys.-Chem. Soc.*, 61, 1421-49 (1929); *Chem. Zentr.*, 1930,II, 391.
(398) Stadnikoff, *Ber.*, 47, 2133-42 (1914).
(399) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 34, 100-2 (1902); *Bull. soc. chim.*, [3], 28, 922 (1902).
(400) Stadnikow, *J. Russ. Phys.-Chem. Soc.*, 47, 2037-44 (1916); *Chem. Zentr.*, 1916,II, 388.
(401) Stadnikow, *J. Russ. Phys.-Chem. Soc.*, 47, 2115-20 (1916); *Chem. Zentr.*, 1916,II, 388.
(402) Stadnikoff, *Ber.*, 57B, 1-8 (1924).
(403) Stark and Garben, *Ber.*, 46, 659-66 (1913).
(404) Stas, *Bull. soc. chim. Belg.*, 34, 188-90 (1925).
(405) Stefanova, *Annuaire univ. Sofia, Faculté phys.-math.*, 40, Livre 2, 147-66 (1943-44); *Chem. Abstr.*, 42, 4156 (1948).
(406) Steiger and Reichstein, *Helv. Chim. Acta*, 20, 1040-54 (1937).
(407) Stevens, *J. Am. Chem. Soc.*, 54, 3732-8 (1932).
(408) Stoermer, *Ber.*, 39, 2288-306 (1906).
(409) Stoermer, Stroh, and Albert, *Ber.*, 68B, 2102-11 (1935).
(410) Süsskind, *Ber.*, 39, 225-6 (1906).
(411) Sweet and Marvel, *J. Am. Chem. Soc.*, 54, 1184-90 (1932).
(412) Tarbell and Lindstrom, *J. Am. Chem. Soc.*, 68, 1930-2 (1946).
(413) Tårbouriech, *Compt. rend.*, 149, 604-6 (1909); *Chem. Zentr.*, 1909,II, 1869.
(414) Theunis, *Bull. acad. roy. Belg.*, [5], 12, 785-96 (1926); *Chem. Zentr.*, 1927,I, 889.
(415) Thiele and Balhorn, *Ber.*, 37, 1463-70 (1904).
(416) Thomas and Bettzieche, *Z. physiol. Chem.*, 140, 244-60 (1924); *Chem. Abstr.*, 19, 635 (1925).
(417) Thomas and Bettzieche, *Z. physiol. Chem.*, 140, 261-72 (1924); *Chem. Abstr.*, 19, 636 (1925).
(418) Tiffeneau, Lévy, and Weill, *Bull. soc. chim.*, [4], 49, 1709-21 (1931).
(419) Tiffeneau and Dorlencourt, *Compt. rend.*, 143, 126-8 (1906); *Chem. Zentr.*, 1906,II, 670.
(420) Tiffeneau and Lévy, *Bull. soc. chim.*, [4], 33, 735-59 (1923).
(421) Tiffeneau and Lévy, *Bull. soc. chim.*, [4], 33, 759-79 (1923).
(422) Tiffeneau and Lévy, *Bull. soc. chim.*, [4], 49, 1738-53 (1931).
(423) Tiffeneau, Oryekhov, and Lévy, *Bull. soc. chim.*, [4], 49, 1840-6 (1931).
(424) Tissier and Grignard, *Compt. rend.*, 132, 1182-4 (1901); *Chem. Zentr.*, 1901,I, 1357.
(425) Treibs, *Ber.*, 65B, 1324-9 (1932).

- (426) Trotman, *J. Chem. Soc.*, 127, 88-95 (1925).
(427) Tschelinzeff and Terentjeff, *Ber.*, 47, 2647-52 (1914).
(428) Tschelinzeff and Terentjeff, *Ber.*, 47, 2652-4 (1914).
(429) Tschitschibabin, *Ber.*, 37, 186-8 (1904).
(430) Tschitschibabin, *Ber.*, 37, 850-3 (1904).
(431) Tschitschibabin, *Ber.*, 38, 561-6 (1905).
(432) Tschitschibabin, *Ber.*, 40, 1810-9 (1907).
(433) Tuot and Guyard, *Bull. soc. chim.*, [5], 14, 1087-96 (1947).
(434) Ullmann and Munzhuber, *Ber.*, 36, 404-10 (1903).
(435) Ushakov and Kuchero, *J. Gen. Chem. (U.S.S.R.)*, 14, 1080-6 (1944); *Chem. Abstr.*, 40, 7185 (1946).
(436) Valeur, *Compt. rend.*, 132, 833-4 (1901); *Chem. Zentr.*, 1901,1, 999.
(437) Valeur, *Bull. soc. chim.*, [3], 29, 683-9 (1903).
(438) van Alphen, *Rec. trav. chim.*, 64, 109-14 (1945).
(439) van Keersbilck, *Bull. soc. chim. Belg.*, 38, 205-11 (1929).
(440) Vène, *Ann. chim.*, [11], 10, 194-279 (1938).
(441) Vène, *Bull. soc. chim.*, [5], 6, 692-7 (1939).
(442) Viquier, *Compt. rend.*, 152, 1490-3 (1911); *Chem. Abstr.*, 5, 3409 (1911).
(443) Viquier, *Compt. rend.*, 153, 955-7 (1911); *Chem. Zentr.*, 1912,1, 20.
(444) Vorländer, Osterburg, and Meye, *Ber.*, 56B, 1136-44 (1923).
(445) Weill, *Bull. soc. chim.*, [4], 49, 1795-806 (1931).
(446) Weizmann and Bergmann, *J. Chem. Soc.*, 1936, 401-2.
(447) Weizmann and Bergmann, *J. Am. Chem. Soc.*, 60, 2647-50 (1938).
(448) Weizmann, Bergmann, and Berlin, *J. Am. Chem. Soc.*, 60, 1331-4 (1938).
(449) Weizmann, Bergmann, and Haskelberg, *J. Chem. Soc.*, 1939, 391-7.
(450) White, Rose, Calingaert, and Soroos, *J. Research Natl. Bur. Standards*, 22, 315-9 (1939).
(451) Whitmore, *Rec. trav. chim.*, 57, 562-8 (1938).
(452) Whitmore and Badertscher, *J. Am. Chem. Soc.*, 55, 1559-67 (1933).
(453) Whitmore, Cosby, Sloatman, and Clarke, *J. Am. Chem. Soc.*, 64, 1801-3 (1942).
(454) Whitmore and Forster, *J. Am. Chem. Soc.*, 64, 2966-8 (1942).
(455) Whitmore and Krueger, *J. Am. Chem. Soc.*, 55, 1528-35 (1933).
(456) Whitmore and Lewis, *J. Am. Chem. Soc.*, 64, 1618-9 (1942).
(457) Whitmore and Lewis, *J. Am. Chem. Soc.*, 64, 2964-6 (1942).
(458) Whitmore, Popkin, Whitaker, Mattil, and Zech, *J. Am. Chem. Soc.*, 60, 2458-62 (1938).
(459) Whitmore and Sloat, *J. Am. Chem. Soc.*, 64, 2966-8 (1942).
(460) Whitmore, Sutherland, and Cosby, *J. Am. Chem. Soc.*, 64, 1360-4 (1942).
(461) Whitmore and Williams, *J. Am. Chem. Soc.*, 55, 406-11 (1933).
(462) Whitmore and Woodburn, *J. Am. Chem. Soc.*, 55, 361-5 (1933).
(463) Wideqvist, *Arkiv Kemi, Mineral. Geol.*, B20, No. 7, 7 pp. (1945); *Chem. Abstr.*, 41, 4453 (1947).
(464) Wideqvist, *Arkiv. Kemi, Mineral. Geol.*, B23, No. 4, 6 pp. (1946); *Chem. Abstr.*, 41, 1615 (1947).
(465) Wieland, Schlichting, and Jacobi, *Z. physiol. Chem.*, 161, 80-115 (1926); *Chem. Abstr.*, 21, 590 (1927).
(466) Wieland, Schlichting, and von Langsdorf, *Z. physiol. Chem.*, 161, 74-9 (1926); *Chem. Abstr.*, 21, 590 (1927).
(467) Willcox and Brunel, *J. Am. Chem. Soc.*, 38, 1821-41 (1916).
(468) Wilson, Roberts, and Young, *J. Am. Chem. Soc.*, 71, 2019-20 (1949).
(469) Wohl and Bernreuther, *Ann.*, 481, 1-29 (1930).
(470) Wohl and Mylo, *Ber.*, 45, 323-49 (1912).
(471) Wood and Comley, *J. Soc. Chem. Ind.*, 42, 429-32T (1923).

- (472) Young and Roberts, *J. Am. Chem. Soc.*, 68, 649-52 (1946).
- (473) Zal'kind and Pletz, *Trans. Leningrad Chem.-Tech. Inst.*, 1, 57-60 (1934); *Chem. Abstr.*, 29, 2908 (1935).
- (474) Zelinsky and Kravts, *J. Russ. Phys.-Chem. Soc.*, 39, 1170 (1908); *Chem. Abstr.*, 2, 1266 (1908).
- (475) Ziegler, *Ann.*, 434, 34-78 (1923).
- (476) Zook, McAleer, and Horwin, *J. Am. Chem. Soc.*, 68, 2404 (1946).
- (477) Zugrăvescu and Zugrăvescu, *Bul. soc. chim. România*, 19A, 85-92 (1937); *Chem. Abstr.*, 33, 4228 (1939).
- (478) Gilman, Kirby, Fothergill, and Harris, *Proc. Iowa Acad. Sci.*, 34, 221-2 (1927); *Chem. Abstr.*, 22, 4504 (1928).
- (479) Paal and Hornstein, *Ber.*, 39, 2823-7 (1906).
- (480) Paal and Weidenkaff, *Ber.*, 39, 2827-33 (1906).
- (481) Lapkin and Golovkova, *J. Gen. Chem. (U.S.S.R.)*, 18, 485-95 (1948); *Chem. Abstr.*, 42, 7273 (1948).
- (482) Feist, Awe, and Kuklinski, *Arch. Pharm.*, 276, 420-31 (1938); *Chem. Abstr.*, 33, 1327 (1939).
- (483) Ullmann and Schlaepfer, *Ber.*, 37, 2001-8 (1904).
- (484) Ullmann and Tcherniak, *Ber.*, 38, 4110-1 (1905).
- (485) Zaher, Sen, and Sidhu, *J. Indian Chem. Soc.*, 24, 293-5 (1949); *Chem. Abstr.*, 42, 5912 (1948).
- (486) Linnell and Roushdi, *Quart. J. Pharm. Pharmacol.*, 14, 270-80 (1941); *Chem. Abstr.*, 36, 2544 (1942).
- (487) Bistrzycki and Gyr, *Ber.*, 37, 655-64 (1904).
- (488) Oddo, *Gazz. chim. ital.*, 41, 1, 273-94 (1911); *Chem. Abstr.*, 5, 2639 (1911).
- (489) Lewis, *J. Chem. Education*, 7, 856-8 (1930).
- (490) Fields, Leafer, and Rohan, *Science*, 109, 35, (1949); *Chem. Abstr.*, 43, 9045 (1949).
- (491) Iotsitch and Kochélef, *J. Russ. Phys.-Chem. Soc.*, 42, 1492 (1910); *Bull. soc. chim.*, [4], 10, 1308 (1911).
- (492) Iotsitch and Kochélef, *J. Russ. Phys.-Chem. Soc.*, 42, 1082 (1910); *Bull. soc. chim.*, [4], 10, 1148 (1911).
- (493) Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).
- (494) Grignard and Liang, *Bull. soc. chim.*, [4], 49, 858-9 (1931).
- (495) Iotsitch and Orelkine, *J. Russ. Phys.-Chem. Soc.*, 42, 1082 (1910); *Bull. soc. chim.*, [4], 10, 1148 (1911).
- (496) Temnikova and Veksler, *J. Gen. Chem. (U.S.S.R.)*, 11, 3-8 (1941); *Chem. Abstr.*, 35, 5459 (1941).
- (497) Temnikova and Veksler, *J. Gen. Chem. (U.S.S.R.)*, 19, 1318-23 (1949); *Chem. Abstr.*, 44, 1056 (1950).
- (498) Petrov and Ol'dekop, *J. Gen. Chem. (U.S.S.R.)*, 18, 859-64 (1948); *Chem. Abstr.*, 43, 107 (1949).
- (499) Anderson and Thomas, *J. Am. Chem. Soc.*, 65, 234-8 (1943).
- (500) Semon and Craig, *J. Am. Chem. Soc.*, 58, 1278-82 (1936).
- (501) Mizuch, *J. Gen. Chem. (U.S.S.R.)*, 16, 1471-4 (1946); *Chem. Zentr.*, 1947, 1, 989; *Chem. Abstr.*, 43, 3819 (1949).
- (502) Grard, *Ann. chim.*, [10], 13, 336-81 (1930).
- (503) Barré and Repentigny, *Can. J. Research*, 27B, 716-20 (1949).
- (504) Arnold, Buckley, and Richter, *J. Am. Chem. Soc.*, 69, 2322-5 (1947).
- (505) Birch and Robinson, *J. Chem. Soc.*, 1943, 501-2.
- (506) Craig, *J. Am. Chem. Soc.*, 57, 195-8 (1935).
- (507) Baeyer and Villiger, *Ber.*, 37, 3191-210 (1904).
- (508) Goldstein and Piolino, *Helv. Chim. Acta*, 10, 334-8 (1927).
- (509) Goldstein and Simo, *Helv. Chim. Acta*, 10, 607-10 (1927).

- (510) Goldstein and Vaymatchar, *Helv. Chim. Acta*, 11, 245-9 (1928).
- (511) Goldstein and Kopp, *Helv. Chim. Acta*, 11, 478-86 (1928).
- (512) Goldstein and Kopp, *Helv. Chim. Acta*, 11, 486-95 (1928).
- (513) Goldstein and Kopp, *Helv. Chim. Acta*, 27, 616-9 (1944).
- (514) Arnold and Searles, *J. Am. Chem. Soc.*, 71, 1150-1 (1959).
- (515) McBee, Pierce, and Higgins, *J. Am. Chem. Soc.*, 74, 1736-7 (1952).
- (516) Kohler and Larsen, *J. Am. Chem. Soc.*, 57, 1448-52 (1935).
- (517) Chelintzev and Karmanov, *J. Russ. Phys.-Chem. Soc.*, 47, 161-9 (1915);
Chem. Abstr., 9, 1472 (1915).
- (518) Salzberg and Marvel, *J. Am. Chem. Soc.*, 50, 1737-44 (1928).
- (519) Davis and Marvel, *J. Am. Chem. Soc.*, 53, 3840-51 (1931).
- (520) Steinkopf and Schmitt, *Ann.*, 533, 264-9 (1938).
- (521) Inhoffen, Bohlman, and Reinefeld, *Chem. Ber.*, 82, 313-6 (1949).
- (522) Gaertner, *J. Am. Chem. Soc.*, 74, 766-7 (1952).
- (523) Haller and Ramart-Lucas, *Compt. rend.*, 159, 143-9 (1914); *Chem. Abstr.*,
8, 3437 (1914).
- (524) Thomas and Bettzieche, *Z. physiol. Chem.*, 140, 279-98 (1924); *Chem.*
Abstr., 19, 636 (1925).

TABLE VIII-IV
REACTIONS OF GRIGNARD REAGENTS WITH LACTONES AND LACTIDES

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₄O₂			
β -Propiolactone (1 mole)	CH ₃ MgI (1 mole)	(C ₃ H ₄ O ₂) _x (3 g., 4.2%); ICH ₂ CH ₂ CO ₂ H (87 g., 43.5%); CH ₃ COCH=CH ₂ (13 g., crude)	22
β -Propiolactone (72 g., 1 mole)	C ₆ H ₅ MgBr (1 mole)	(C ₃ H ₄ O ₂) _x (6.5 g., 9.6%); BrCH ₂ CH ₂ CO ₂ H (64 g., 43.0%); H ₂ C=CHCOC ₆ H ₅ (21.2%)*	22
β -Propiolactone (72 g., 1 mole)	C ₆ H ₅ MgBr (1 mole)	(C ₃ H ₄ O ₂) _x (31 g., 43.1%); BrCH ₂ CH ₂ CO ₂ H (44 g., 28.7%); H ₂ C=CHCOC ₆ H ₅ †	22
β -Propiolactone (72 g., 1 mole)	(C ₆ H ₅) ₂ Mg (from 1 mole C ₆ H ₅ MgBr)	(C ₃ H ₄ O ₂) _x (84 g.); H ₂ C=CHCOC ₆ H ₅ (12 g., crude)	22
β -Propiolactone (1 mole)	C ₆ H ₅ CH ₂ MgCl (1 mole)	(C ₃ H ₄ O ₂) _x (16.1 g., 22.4%); ClCH ₂ CH ₂ CO ₂ H (17.5 g., 16.1%); C ₆ H ₅ (CH ₂) ₃ CO ₂ H (53.2 g., 32.4%)	22
C₄H₆O₂			
γ -Butyrolactone	CH ₃ MgI	HO(CH ₃) ₂ CCH ₂ CH ₂ CH ₂ OH	28
γ -Butyrolactone (7.5 g.)	C ₆ H ₅ MgBr (13.7 g. C ₆ H ₅ Br)	HO(C ₆ H ₅) ₂ CCH ₂ CH ₂ CH ₂ OH (2.0 g.)	59
C₅H₈O₂			
γ -Valerolactone	CH ₃ MgI	HO(CH ₃) ₂ CCH ₂ CH ₂ CH(CH ₃)OH	32
C₆H₈O₄			
Lactide†	C ₆ H ₅ MgBr	HO(C ₆ H ₅) ₂ CCH(CH ₃)OH	39

* Gradual (1.25 hrs.) addition of Et₂O-lactone solution to Grignard reagent solution at -6 to 0°.

† Addition of Grignard reagent solution to Et₂O-lactone solution at -35 to -28°.

‡ Dilactylic anhydride.

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₀O₃			
α -Hydroxy- β , β -dimethyl- γ -butyrolactone (684.6 mg.)	CH ₃ MgI (3.0 ml. CH ₃ I)	HO(CH ₃) ₂ CCH(OH)C(CH ₃) ₂ CH ₂ OH (850.0 mg.)	53
α -Hydroxy- β , β -dimethyl- γ -butyrolactone (400.0 mg.)	C ₆ H ₅ MgBr (5.8 g. C ₆ H ₅ Br)	HO(C ₆ H ₅) ₂ CCH(OH)C(CH ₃) ₂ CH ₂ OH (870.0 mg.)	53
2,2,5-Trimethyl-1,3-dioxolan-4-one	<i>t</i> -C ₄ H ₉ MgCl	<i>i</i> -C ₃ H ₇ OCH(CH ₃)CO ₂ H (20%)	17
C₇H₁₀O₂			
2-Methylene-4-hydroxy-4-methyl-pentanoic acid lactone (or 2,4-dimethyl-4-hydroxy-2-pentenoic acid lactone) (25 g.)	CH ₃ MgI (2.5 equiv.)	HO(CH ₃) ₂ CCH ₂ C(=CH ₂)C(C ₆ H ₅) ₂ OH [or HO(CH ₃) ₂ CCH=C(CH ₃)C(C ₆ H ₅) ₂ OH] (30 g., crude)	31
C₇H₁₂O₃			
α , γ -Dihydroxy- α , γ -dimethyl-valeric acid γ -lactone	CH ₃ MgI (3 equiv.)	HO(CH ₃) ₂ CCH ₂ C(OH)(CH ₃)C(CH ₃) ₂ OH	30
α , γ -Dihydroxy- α , γ -dimethyl-valeric acid γ -lactone	C ₆ H ₅ MgBr (3 equiv.)	2,2,4-Trimethyl-4-hydroxy-5-5-diphenyl-tetrahydrofuran	30
α , γ -Dihydroxy- α , γ -dimethyl-valeric acid γ -lactone	C ₆ H ₅ MgBr	HO(CH ₃) ₂ CCH ₂ C(OH)(CH ₃)C(C ₆ H ₅) ₂ OH	31
2,2,5,5-Tetramethyl-1,3-dioxolan-4-one	<i>t</i> -C ₄ H ₉ MgCl	<i>i</i> -C ₃ H ₇ OC(CH ₃) ₂ CO ₂ H (50%)	17
C₇H₁₃O₂N			
α -Amino- α , γ -dimethyl- γ -hydroxy-valeric acid γ -lactone	CH ₃ MgI (3 equiv.)	HO(CH ₃) ₂ CCH ₂ C(NH ₂)(CH ₃)C(CH ₃) ₂ OH	30
α -Amino- α , γ -dimethyl- γ -hydroxy-valeric acid γ -lactone	C ₆ H ₅ MgBr (3 equiv.)	HO(CH ₃) ₂ CCH ₂ C(NH ₂)(CH ₃)C(C ₆ H ₅) ₂ OH	30
C₈H₆O₂			
Phthalide	CH ₃ MgBr (3 equiv.)	2-HOCH ₂ C ₆ H ₄ C(CH ₃) ₂ OH	36

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₆O₂ (cont.)			
Phthalide	C ₂ H ₅ MgBr	2-HOCH ₂ C ₆ H ₄ C(C ₂ H ₅) ₂ OH	36
Phthalide	<i>i</i> -C ₃ H ₇ MgX	2-HOCH ₂ C ₆ H ₄ C(<i>i</i> -C ₃ H ₇) ₂ OH	36
Phthalide (6.7 g.)	C ₆ H ₅ MgBr (27.3 g. C ₆ H ₅ Br)	2-HOCH ₂ C ₆ H ₄ C(C ₆ H ₅) ₂ OH (7.3 g.)	47,65
Phthalide	C ₆ H ₅ CH ₂ MgCl (3 equiv.)	2-HOCH ₂ C ₆ H ₄ C(CH ₂ C ₆ H ₅) ₂ OH	36
C₉H₆O₂			
Coumarin (30 g.)	CH ₃ MgI (65 g. CH ₃ I)	2,2-Dimethyl-1,2-benzopyran (26 g., 80%)	29
Coumarin	CH ₃ MgI	2-Methyl-1-benzopyrylium iodide	14
Coumarin	CH ₃ MgI	2-HOC ₆ H ₄ CH=CHC(CH ₃) ₂ OH; 2,2-dimethyl-1,2-benzopyran	49
Coumarin (0.125 mole)	CH ₃ MgX (0.4 mole CH ₃ X)	2,2-Dimethyl-1,2-benzopyran (59%)	48
Coumarin (50 g.)	C ₂ H ₅ MgBr (80 g. C ₆ H ₅ Br)	2,2-Diethyl-1,2-benzopyran (31 g., 48.8%)	29
Coumarin (25 g.)	C ₂ H ₅ MgBr (40 g. C ₂ H ₅ Br)	2-HOC ₆ H ₄ CH=CHC(C ₂ H ₅) ₂ OH (32 g., crude)	49
Coumarin (0.125 mole)	C ₂ H ₅ MgX (0.4 mole C ₂ H ₅ X)	2,2-Diethyl-1,2-benzopyran (64%)	48
Coumarin (0.125 mole)	<i>n</i> -C ₃ H ₇ MgX (0.4 mole C ₃ H ₇ X)	2,2-Di- <i>n</i> -propyl-1,2-benzopyran (68%)	48
Coumarin (24 g.)	<i>i</i> -C ₃ H ₇ MgBr (41 g. C ₃ H ₇ Br)	Unidentified products	29
Coumarin (22 g.)	<i>n</i> -C ₄ H ₉ MgBr (45.2 g. C ₄ H ₉ Br)	2-HOC ₆ H ₅ CH=CHC(<i>n</i> -C ₄ H ₉) ₂ OH; 2,2-di- <i>n</i> -butyl-1,2-benzopyran (17-18 g.)	49
Coumarin (0.125 mole)	<i>n</i> -C ₄ H ₉ MgX (0.4 mole C ₄ H ₉ X)	2,2-Di- <i>n</i> -butyl-1,2-benzopyran (70%)	48
Coumarin (0.125 mole)	<i>n</i> -C ₅ H ₁₁ MgX (0.4 mole C ₅ H ₁₁ X)	2,2-Di- <i>n</i> -amyl-1,2-benzopyran (77.3%)	48
Coumarin (30 g.)	C ₆ H ₅ MgBr (65 g. C ₆ H ₅ Br)	2,4-Diphenyl-2-chromanol* (10 g.)	29
Coumarin (40 g.)	C ₆ H ₅ MgBr (90 g. C ₆ H ₅ Br)	2,4-Diphenyl-2-chromanol (45%); 2,2-diphenyl-1,2-benzopyran (35%)	34
Coumarin	C ₆ H ₅ MgBr (+ fuming HCl)	2-Phenyl-1-benzopyrylium chloride	14
Coumarin (0.125 mole)	<i>n</i> -C ₆ H ₁₃ MgX (0.4 mole C ₆ H ₁₃ X)	2,2-Di- <i>n</i> -hexyl-1,2-benzopyran (83%)	48
Coumarin (30 g.)	C ₆ H ₅ CH ₂ MgCl (80 g. C ₇ H ₇ Cl)	CH ₃ C ₆ H ₅ ; (C ₆ H ₅ CH ₂ -) ₂ ; 2-HOC ₆ H ₄ CH=CHCOCH ₂ C ₆ H ₅ (47 g.)	29

* Originally reported by Houben (29) as 2-HOC₆H₄CH=CHC(C₆H₅)₂OH; *c/f.*, however, Lowenbein, *et al.* (34).

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₆O₂ (cont.)			
Coumarin (0.125 mole)	<i>n</i> -C ₇ H ₁₅ MgX	2,2-Di- <i>n</i> -heptyl-1,2-benzopyran (91.5%)	48
Coumarin (10 g.)	1-C ₁₀ H ₇ MgBr (32.5 g. C ₁₀ H ₇ Br)	2,4-Di- α -naphthyl-2-chromanol	34,29
Isocoumarin (21 g., 0.14 mole)	C ₆ H ₅ MgBr (0.13 mole) (+ 70% HClO ₄)	1-Phenyl-2-benzopyrilium perchlorate (9 g., 21%)	66
C₉H₆O₃			
4-Hydroxycoumarin (5 g.)	C ₆ H ₅ MgBr (14.5 g. C ₆ H ₅ Br)	2,2-Diphenyl-4-hydroxy-1,2-benzopyran	26
C₉H₇O₂N			
2-Methyl-3,1,4-benzoxaz-4-one (30 g.)	C ₆ H ₅ MgBr (32.3 g. C ₆ H ₅ Br)	2-CH ₃ CONHC ₆ H ₄ (C ₆ H ₅) ₂ COH (10 g., 23%)	33
2-Methyl-3,1,4-benzoxaz-4-one (10 g.)	C ₆ H ₅ MgBr (9.7 g. C ₆ H ₅ Br)	C ₆ H ₅ COC ₆ H ₄ -2-NHCOCH ₃ (5.2 g., 33%)	33
2-Methyl-3,1,4-benzoxaz-4-one	C ₆ H ₅ CH ₂ MgCl	Unidentified oily product	33
2-Methyl-3,1,4-benzoxaz-4-one	2-CH ₃ C ₆ H ₄ MgBr	<i>o</i> -CH ₃ C ₆ H ₄ COC ₆ H ₄ -2-NHCOCH ₃ (43%)	33
2-Methyl-3,1,4-Benzoxaz-4-one	3-CH ₃ C ₆ H ₄ MgBr (<i>ca.</i> 1 equiv.)	<i>m</i> -CH ₃ C ₆ H ₄ COC ₆ H ₄ -2-NHCOCH ₃ (10% overall yield of amine upon hydrolysis)	33
2-Methyl-3,1,4-benzoxaz-4-one (15 g.)	1-C ₁₀ H ₇ MgBr	α -C ₁₀ H ₇ COC ₆ H ₄ -2-NHCOCH ₃ (2.4 g.); 2-CH ₃ CONHC ₆ H ₄ (α -C ₁₀ H ₇) ₂ COH (?) (1.2 g.)	33
2-Methyl-3,1,4-benzoxaz-4-one (15.0 g.)	1-C ₁₀ H ₇ MgBr (17.7 g. C ₁₀ H ₇ Br)	α -C ₁₀ H ₇ COC ₆ H ₄ -2-NHCOCH ₃ (11.6 g., 47%)	33
2-Methyl-3,1,4-benzoxaz-4-one (7.8 g.)	2-C ₁₀ H ₇ MgBr (10.0 g. C ₁₀ H ₇ Br)	β -C ₁₀ H ₇ COC ₆ H ₄ -2-NHCOCH ₃ (yielding 1 g., 8.3% 2-C ₁₀ H ₇ COC ₆ H ₄ -2-NH ₂ upon hydrolysis)	33
2-Methyl-3,1,4-benzoxaz-4-one (15.0 g.)	2-CH ₃ C ₁₀ H ₆ -1-MgBr (19.6 g. C ₁₁ H ₉ Br)	2-CH ₃ C ₁₀ H ₆ -1-COC ₆ H ₄ -2-NHCOCH ₃ (9.5 g., 34%)	33
C₉H₈O₂			
3,4-Dihydrocoumarin (5 g.)	C ₂ H ₅ MgBr (7.4 g. C ₂ H ₅ Br)	2-HOC ₆ H ₄ CH ₂ CH ₂ (C ₂ H ₅) ₂ COH (6 g.)	51

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₈O₂ (<i>cont.</i>)			
3,4-Dihydrocoumarin (5 g.)	<i>n</i> -C ₃ H ₇ MgCl (7.8 g. C ₃ H ₇ Cl)	2-HOC ₆ H ₄ CH ₂ CH ₂ (<i>n</i> -C ₃ H ₇) ₂ COH (6.15 g.)	51
3,4-Dihydrocoumarin (14.8 g.)	<i>n</i> -C ₄ H ₉ MgBr (28.0 g. C ₄ H ₉ Br)	2-HOC ₆ H ₄ CH ₂ CH ₂ (<i>n</i> -C ₄ H ₉) ₂ COH (25 g.)	49
3-Methylphthalide (5.5 g.)	CH ₃ MgI (17.8 g. CH ₃ I)	1-Methylene-3-methylphthalan	38
C₁₀H₈O₂			
3-Methylcoumarin (10 g.)	C ₆ H ₅ MgBr (3 equiv.)	2,4-Diphenyl-3-methyl-2-chromanol	26
4-Methylcoumarin (10 g.)	C ₆ H ₅ MgBr (30 g. C ₆ H ₅ Br)	2,2-Diphenyl-4-methyl-1,2-benzopyran	26
C₁₀H₈O₃			
4-Methoxycoumarin (5 g.)	C ₆ H ₅ MgBr (14 g. C ₆ H ₅ Br)	2,2-Diphenyl-4-methoxy-1,2-benzopyran (7 g.)	26
4-Methoxycoumarin	4-CH ₃ OC ₆ H ₄ MgBr	2,2-Di- <i>p</i> -anisyl-4-methoxy-1,2-benzopyran	26
C₁₀H₁₀O₂			
3,3-Dimethyl phthalide	C ₆ H ₅ MgBr (12 g. C ₆ H ₅ Br)	2-C ₆ H ₅ COC ₆ H ₄ C(CH ₃) ₂ OH, or the corresponding hydroxyphthalan (9.7 g.)	11
C₁₀H₁₄O₃			
α -(5-Methyl-2-furylidene)- γ -valerolactone *	CH ₃ MgI	C ₁₂ H ₂₀ O ₂ †	32
C₁₁H₁₀O₂			
4,6-Dimethylcoumarin	C ₆ H ₅ MgBr	2,4-Diphenyl-4,6-dimethyl-2-chromanol	34
4,6-Dimethylcoumarin (5 g.)	C ₆ H ₅ MgBr	2,2-Diphenyl-4,6-dimethyl-1,2-benzopyran, m. 126°	26

* Divalerolactone.

† Described as the anhydride corresponding to the expected glycol.

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₀O₂ (cont.)			
4,7-Dimethylcoumarin	C ₆ H ₅ MgBr	2,4-Diphenyl-4,7-dimethyl-2-chromanol	34
4,7-Dimethylcoumarin	C ₆ H ₅ MgBr	2-HO-4-CH ₃ C ₆ H ₃ C(CH ₃)=CHC(C ₆ H ₅) ₂ OH (10%); 2,2-Diphenyl-4,7-dimethyl-1,2-benzopyran (75%)	26
5,7-Dimethylcoumarin	C ₆ H ₅ MgBr	2,4-Diphenyl-5,7-dimethyl-2-chromanol	34
C₁₁H₁₁O₃Br			
2,2-Dimethyl-5- <i>p</i> -bromophenyl-1,3-dioxolan-4-one	<i>t</i> -C ₄ H ₉ MgCl	<i>i</i> -C ₃ H ₇ OCH(C ₆ H ₄ - <i>p</i> -Br)CO ₂ H (71%)	17
C₁₁H₁₂O₃			
2,2-Dimethyl-5-phenyl-1,3-dioxolan-4-one (38.4 g.)	<i>t</i> -C ₄ H ₉ MgCl (55.8 g. C ₄ H ₉ Cl)	<i>i</i> -C ₃ H ₇ OCH(C ₆ H ₅)CO ₂ H (22 g., 57%); <i>i</i> -C ₄ H ₈	17
2,2-Dimethyl-5-phenyl-1,3-dioxolan-4-one (76.8 g.)	<i>t</i> -C ₄ H ₉ MgCl (92 g. C ₄ H ₉ Cl)	<i>i</i> -C ₃ H ₇ OCH(C ₆ H ₅)CO ₂ H (34 g., 45%); <i>i</i> -C ₄ H ₈ [recovered as (CH ₃) ₂ CBrCH ₂ Br, 20 g., 24%]	17
2,2-Dimethyl-5-phenyl-1,3-dioxolan-4-one	C ₆ H ₅ MgBr	HO(C ₆ H ₅) ₂ CCH(C ₆ H ₅)OH (66%)	15,17
2,2-Dimethyl-5-phenyl-1,3-dioxolan-4-one (96 g.)	2-CH ₃ C ₆ H ₄ MgBr (342 g. C ₇ H ₇ Cl)	HO(2-CH ₃ C ₆ H ₄) ₂ CCH(C ₆ H ₅)OH (30.5 g.)	17
2,2-Dimethyl-5-phenyl-1,3-dioxolan-4-one	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	"Intractable oil"	17
C₁₁H₁₄O₈			
Triacetyl- α -arabonic acid lactone	C ₆ H ₅ MgBr (11 equiv.)	HO(C ₆ H ₅) ₂ C[CH(OH)] ₃ CH ₂ OH (1,1-Diphenyl- α -arabitol) (15-16%); CH ₃ (C ₆ H ₅) ₂ COH	41
Triacetyl- α -arabonic acid lactone (4.5 parts)	C ₆ H ₅ CH ₂ MgCl (25.3 parts C ₇ H ₇ Cl)	HO(C ₆ H ₅ CH ₂) ₂ C[CH(OH)] ₃ CH ₂ OH (1,1-Dibenzyl- α -arabitol) (<i>ca.</i> 15%); CH ₃ (C ₆ H ₅ CH ₂) ₂ COH	41
Triacetyl- α -arabonic acid lactone	4-CH ₃ C ₆ H ₅ MgBr (11 equiv.)	HO(4-CH ₃ C ₆ H ₄) ₂ C[CH(OH)] ₃ CH ₂ OH (1,1-Di- <i>p</i> -tolyl- α -arabitol) (15%); CH ₃ (4-CH ₃ C ₆ H ₄) ₂ COH	41

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₁₂O₃			
3,4-Dimethyl-7-methoxycoumarin* (10 g.)	C ₆ H ₅ MgBr (2 equiv.) (+ CONCHCl)	2-Phenyl-3,4-dimethyl-7-methoxybenzopyrylium chloride (quant.)	27
C₁₂H₁₂O₄			
4-Carbomethoxymethyl-3,4-dihydrocoumarin (2.1 g.)	C ₆ H ₅ MgBr (excess)	2-HOC ₆ H ₄ CH[CH ₂ C(C ₆ H ₅) ₂ OH] ₂	18
C₁₂H₁₂O₅			
3,5,7-Trimethoxycoumarin (1.5 g.)	C ₆ H ₅ MgBr (3 g. C ₆ H ₅ Br) (+ 20% HCl)	2-Phenyl-3,5,7-trimethoxy-1-benzopyrylium chloride (1.3 g., including 13.3% H ₂ O)	60
3,5,7-Trimethoxycoumarin (1 g.)	4-CH ₃ OC ₆ H ₄ MgBr (3.75 g.) C ₆ H ₅ Br (+ 20% HCl)	2- <i>p</i> -Anisyl-3,5,7-trimethoxy-1-benzopyrylium chloride (0.8–1.0 g., <i>ca.</i> 60%)	61
3,5,7-Trimethoxycoumarin (0.9 g.)	2,4-(CH ₃ O) ₂ C ₆ H ₃ MgI (3 g. C ₈ H ₉ IO ₂) (+ 20% HCl)	2-(2,4-Dimethoxyphenyl)-3,5,7-trimethoxy-1-benzopyrylium chloride (0.8 g., >50%)	60
3,5,7-Trimethoxycoumarin (0.3 g.)	3,4-(CH ₃ O) ₂ C ₆ H ₃ MgI (3.3 g. C ₈ H ₉ IO ₂) (+ 20% HCl)	2-(3,4-Dimethoxyphenyl)-3,5,7-trimethoxy-1-benzopyrylium chloride	61
C₁₂H₁₃O₃			
5,7,8-Trimethyl-6-hydroxy-3,4-dihydrocoumarin (1.33 g.)	CH ₃ MgI (4.00 g. CH ₃ I)	2,2,5,7,8-Pentamethyl-6-hydroxychroman and corresponding carbinol	50,62
5,7,8-Trimethyl-6-hydroxy-3,4-dihydrocoumarin (1.33 g.)	CH ₃ MgI (0.62 g. Mg)	2-Methyl-4-(2,5-dihydroxy-3,4,6-trimethylphenyl)butanol-2; 2,2,5,7,8-pentamethyl-6-hydroxychroman	51
C₁₂H₁₄O₃			
2,2-Dimethyl-5- <i>p</i> -tolyl-1,3-dioxolan-4-one	<i>t</i> -C ₄ H ₉ MgCl	<i>i</i> -C ₃ H ₇ OCH(C ₆ H ₄ - <i>p</i> -CH ₃)CO ₂ H (66%)	17

* Heilbron and Zaki (27) erroneously reported this compound as the isomeric 2,3-dimethyl-7-methoxychromone. See: Canter, Curd, and Robertson, *J. Chem. Soc.*, 1931, 1255–65; Hamer, Heilbron, Reade, and Walls, *ibid.*, 1932, 251–60.

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₁₄O₄			
3,3-Diethylphthalide	C ₆ H ₅ MgBr	2-C ₆ H ₅ COC ₆ H ₄ C(C ₂ H ₅) ₂ OH, or the corresponding hydroxyphthalan	11
C₁₃H₈O₂			
6-Dibenzo[<i>b,d</i>]pyrone	C ₆ H ₅ MgBr	6-Phenyldibenzo[<i>b,d</i>]pyrylium hydroxide	13
C₁₃H₈O₃			
3-Hydroxy-6-dibenzo[<i>b,d</i>]pyrone (10 g.)	CH ₃ MgI (48 g. CH ₃ I)	3-Hydroxy-6,6-dimethyl-6-dibenzo[<i>b,d</i>]pyran (4.3 g., 40%)	7
C₁₃H₉O₂N			
2-Methyl-4-naphth[2,3- <i>d</i>][1,3]oxazin- 4-one (15 g.)	C ₆ H ₅ MgBr	2-CH ₃ CONHC ₁₀ H ₆ -3-C(C ₆ H ₅) ₂ OH (?) (1.2 g.); 2-CH ₃ CONHC ₁₀ H ₆ -3-COC ₆ H ₅ (8 g., 39%)	33
2-Methyl-4-naphth[2,3- <i>d</i>][1,3]oxazin- 4-one (15 g.)	C ₆ H ₅ CH ₂ MgCl	2-CH ₃ CONHC ₁₀ H ₆ -3-C(CH ₂ C ₆ H ₅) ₂ OH ("very small yield")	33
2-Methyl-4-naphth[2,3- <i>d</i>][1,3]oxazin- 4-one	C ₆ H ₅ CH ₂ MgCl	3-CH ₃ CONH-2-C ₁₀ H ₆ (C ₆ H ₅ CH ₂) ₂ COH (small am't); no ketone	33
2-Methyl-4-naphth[2,3- <i>d</i>][1,3]oxazin- 4-one	2-C ₁₀ H ₇ MgBr	2-CH ₃ CONHC ₁₀ H ₆ -3-CO-2-C ₁₀ H ₇	33
2-Methyl-4-naphth[2,3- <i>d</i>][1,3]oxazin- 4-one	2-C ₁₀ H ₇ MgBr	2-(β-C ₁₀ H ₇ CO)-3-CH ₃ CONHC ₁₀ H ₆	33
C₁₃H₁₀O₃N			
3-Methyl-10-hydroxy-1,2,3,4-tetra- hydropyridino[3,4- <i>c</i>]benzo- [<i>e</i>]pyran-5-one (5 g.)	CH ₃ MgI (10.5 ml. CH ₃ I)	3,5,5-Trimethyl-10-hydroxy-1,2,3,4-tetrahydro- pyridino[3,4- <i>c</i>]benzo[<i>e</i>]pyran (0.5 g.)	10

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₁₀O₃N (<i>cont.</i>)			
3-Methyl-8-hydroxy-1,2,3,4-tetrahydropyridino[3,4- <i>c</i>]benzo[<i>e</i>]pyran-5-one (4.2 g.)	CH ₃ MgI (8 ml. CH ₃ I)	3,5,5-Trimethyl-8-hydroxy-1,2,3,4-tetrahydropyridino[3,4- <i>c</i>]benzo[<i>e</i>]pyran (1.8 g.)	10
C₁₃H₁₂O₄			
4,7-Dimethyl-5-acetoxycoumarin	CH ₃ MgI (excess)	2,2,4,7-Tetramethyl-5-hydroxy-1,2-benzopyran	44
C₁₄H₁₀O₂			
3-Phenylphthalide (excess)	C ₆ H ₅ MgBr	2-[C ₆ H ₅ CH(OH)]C ₆ H ₄ C(C ₆ H ₅) ₂ OH	23,24
3-Phenylphthalide	C ₆ H ₅ MgBr (excess)	1,3-Diphenylphthalan-1-ol	23,24
3-Phenylphthalide (6.3 g.)	C ₆ H ₅ MgBr (9.6 g. C ₆ H ₅ Br)	1,3-Diphenylphthalan-1-ol	47
3-Phenylphthalide (10 g.)	C ₆ H ₅ CH ₂ MgCl (7 g. C ₇ H ₇ Cl)	1-Phenyl-3-benzylidenephthalan (5.3 g.)	55
3-Phenylphthalide	4-CH ₃ C ₆ H ₄ MgBr	1- <i>p</i> -Tolyl-3-phenylphthalan-1-ol	30
C₁₄H₁₂O₃N			
3,8-Dimethyl-10-hydroxy-1,2,3,4-tetrahydropyridino[3,4- <i>c</i>]benzo[<i>e</i>]pyran-5-one (4.9 g.) (5-Hydroxy-7-methyl- <i>N</i> -methyltetrahydropyrido[3,4- <i>d</i>]coumarin	CH ₃ MgI (11 ml. CH ₃ I)	3,5,5,8-Tetramethyl-10-hydroxy-1,2,3,4-tetrahydropyridino[3,4- <i>c</i>]benzo[<i>e</i>]pyran	10
C₁₄H₁₄O₃			
1-Hydroxy-3-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone (1.5 g.)	CH ₃ MgI (6 ml. CH ₃ I)	1-Hydroxy-3,6,6-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (1.0 g., 63%) (after HBr dehydration)	2
C₁₄H₁₄O₄			
1,3-Dihydroxy-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1,3-Dihydroxy-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran	44

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₈O₃			
2,2-Dimethyl-5-mesityl-1,3-dioxolan-4-one	<i>t</i> -C ₄ H ₉ MgCl	<i>i</i> -C ₃ H ₇ OCH(Mes)CO ₂ H (80%)	17
2,2-Dimethyl-5-mesityl-1,3-dioxolan-4-one (50 g.)	C ₆ H ₅ MgBr (4 equiv.)	HO(C ₆ H ₅) ₂ CCH(Mes)OH (?) [yielding (C ₆ H ₅) ₂ CHCOMes on AcH-HCl reflux]	16
C₁₄H₁₈O₁₀			
Tetraäcetyl-D-glucuronic acid γ -lactone (3 g.)	C ₆ H ₅ MgBr (12 equiv.)	(C ₆ H ₅) ₂ C(OH)(CHOH) ₄ CH ₂ OH (1,1-Diphenyl-D-sorbitol) (10-12%); CH ₃ (C ₆ H ₅) ₂ COH	40
Tetraäcetyl-D-glucuronic acid γ -lactone	C ₆ H ₅ MgBr (13 equiv.)	(C ₆ H ₅) ₂ C(OH)(CHOH) ₄ CH ₂ OH (1,1-Diphenyl-D-sorbitol) (25%); CH ₃ (C ₆ H ₅) ₂ COH	40
Tetraäcetyl-D-glucuronic acid γ -lactone (5.5 g.)	C ₆ H ₅ CH ₂ MgCl (30 g. C ₇ H ₇ Cl)	(C ₆ H ₅ CH ₂) ₂ C(OH)(CHOH) ₄ CH ₂ OH (1,1-Dibenzyl-D-sorbitol) (0.83-1.24 g. crude); CH ₃ (C ₆ H ₅ CH ₂) ₂ COH	42
Tetraäcetyl-D-glucuronic acid γ -lactone (5.5 g.)	4-CH ₃ C ₆ H ₄ MgBr (13 equiv.)	(4-CH ₃ C ₆ H ₄) ₂ C(OH)(CHOH) ₄ CH ₂ OH (1,1-Di- <i>p</i> -tolyl-D-sorbitol) (0.5-0.8 g., crude; 0.45-0.61 g., 8-10%, pure); CH ₃ (4-CH ₃ C ₆ H ₄) ₂ COH	42
Tetraäcetyl-D-galactonic acid γ -lactone (10 g.)	C ₆ H ₅ MgBr (14 equiv.)	(C ₆ H ₅) ₂ C(OH)(CHOH) ₄ CH ₂ OH (1,1-Diphenyl-dulcitol) (30%); CH ₃ (C ₆ H ₅) ₂ COH	43,42
Tetraäcetyl-D-galactonic acid γ -lactone (5 g.)	4-CH ₃ C ₆ H ₄ MgBr (14 equiv.)	(4-CH ₃ C ₆ H ₄) ₂ C(OH)(CHOH) ₄ CH ₂ OH (1,1-Di- <i>p</i> -tolyl-dulcitol) (10-20%); CH ₃ (4-CH ₃ C ₆ H ₄) ₂ COH	42
C₁₅H₁₀O₂			
3-Benzylidenephthalide (44.5 g., 0.2 mole)	C ₆ H ₅ MgBr (78.5 g. C ₆ H ₅ Br)	2,3-Diphenyl-1-indenone (34-40 g., 60-71%)	9,57
3-Benzylidenephthalide (30 g.)	C ₆ H ₅ CH ₂ MgCl (24 g. C ₇ H ₇ Cl)	2-Phenyl-3-benzyl-1-indenone (26%); 1,1-dibenzyl-3-benzylidenephthalan; 1,3-dibenzylidenephthalan	56,54

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₀O₂ (cont.)			
3-Benzylidenephthalide (6.5 g.)	2-CH ₃ C ₆ H ₄ MgBr (5 g. C ₇ H ₇ Br)	2-Phenyl-3- <i>o</i> -tolyl-1-indenone (3.1 g.)	57
3-Benzylidenephthalide (4.15 g.)	1-C ₁₀ H ₇ MgBr (5.15 g. C ₁₀ H ₇ Br)	2-Phenyl-3- <i>α</i> -naphthyl-1-indenone (2.2 g.)	57
3-Phenylcoumarin (40 g.)	C ₆ H ₅ MgBr (100 g. C ₆ H ₅ Br)	2,3,4-Triphenyl-2-chroman-ol (70%)	35
3-Phenylcoumarin (25 g.)	1-C ₁₀ H ₇ MgBr (14 g. C ₁₀ H ₇ Br)	2,4-Di- <i>α</i> -naphthyl-3-phenyl-1,4-benzopyran (23 g., 69%)	35
3-Phenyl-2,1-benzopyrone* (23 g.)	C ₆ H ₅ CH ₂ MgCl (16 g. C ₇ H ₇ Cl)	1-C ₆ H ₅ COCH ₂ C ₆ H ₄ -2-COCH ₂ C ₆ H ₅ (18 g.)	58
C₁₅H₁₀O₃			
1-Methyl-3-hydroxy-6-dibenzo- [<i>b,d</i>]pyrone (7 g.)	CH ₃ MgI (31 g. CH ₃ I)	1,6,6-Trimethyl-3-hydroxy-6-dibenzo[<i>b,d</i>]pyran (5.5 g., 75%)	7
C₁₅H₁₂O₂			
3- <i>o</i> -Tolylphthalide	C ₆ H ₅ MgBr (large excess)	2-[<i>o</i> -CH ₃ C ₆ H ₄ CH(OH)]C ₆ H ₄ C(C ₆ H ₅) ₂ OH	25
3- <i>o</i> -Tolylphthalide	4-CH ₃ C ₆ H ₄ MgBr (large excess)	2-[<i>o</i> -CH ₃ C ₆ H ₄ CH(OH)]C ₆ H ₄ C(C ₆ H ₄ - <i>p</i> -CH ₃) ₂ OH	25
3- <i>p</i> -Tolylphthalide (50 g.)	C ₆ H ₅ MgBr (8 g. Mg)	1-Phenyl-3- <i>p</i> -tolylphthalen-1-ol	25
3- <i>p</i> -Tolylphthalide	C ₆ H ₅ MgBr (1.5 equiv.)	1-Phenyl-3- <i>p</i> -tolylisobenzofuran	25
3- <i>p</i> -Tolylphthalide (10.0 g.)	C ₆ H ₅ CH ₂ MgCl (5.3 g. C ₇ H ₇ Cl)	1- <i>p</i> -Tolyl-3-benzylidenephthalan (50%)	55
3- <i>p</i> -Tolylphthalide	4-CH ₃ C ₆ H ₄ MgBr	1,3-Di- <i>p</i> -tolylphthalan-1-ol; 1,3-di- <i>p</i> - tolylisobenzofuran	25
C₁₅H₁₄O₄			
2-Acetoxy-7,8,9,10-tetrahydro- 6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	2-Hydroxy-6,6-dimethyl-7,8,9,10-tetrahydro- 6-dibenzo[<i>b,d</i>]pyran (60%)	21
3-Acetoxy-7,8,9,10-tetrahydro- 6-dibenzo[<i>b,d</i>]pyrone (28 g.)	CH ₃ MgI (100 g. CH ₃ I)	3-Hydroxy-6,6-dimethyl-7,8,9,10-tetrahydro- 6-dibenzo[<i>b,d</i>]pyran (14 g.)	21
7-Methyl-9-acetoxy-2,3-dihydro- benzo[<i>b</i>]cyclopenta[<i>d</i>]pyran 4-(1 <i>H</i>)-one	CH ₃ MgI (excess)	4,4,7-Trimethyl-1,2,3,4-tetrahydrobenzo- [<i>b</i>]cyclopenta[<i>d</i>]pyran-9-ol	44

* Isobenzophthalide.

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₆O₂			
8,9-Dimethyl-6a,7,10,10a-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI	1,2-Dimethyl-4-(<i>o</i> -hydroxyphenyl)-5-(α -hydroxyisopropyl)-1-cyclohexene (85%)	37
C₁₅H₁₆O₃			
1-Hydroxy-3,9-dimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone (4.5 g.)	CH ₃ MgI (12 ml. CH ₃ I)	1-Hydroxy-3,6,6,9-tetramethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (3.7 g., 77%) (after HBr dehydration)	2
C₁₆H₁₆O₄			
1-Acetoxy-3-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3,6,6-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (60%)	21
2-Acetoxy-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone (5.0 g.)	CH ₃ MgI (22.5 g. CH ₃ I)	2-Hydroxy-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (4 g.)	20
3-Acetoxy-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	3-Hydroxy-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran	21
C₁₆H₁₈O₃			
1-Hydroxy-3-ethyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3-ethyl-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran	63
C₁₇H₁₈O₄			
1-Acetoxy-3,9-dimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3,6,6,9-tetramethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran	21
1-Acetoxy-3,9-dimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	<i>n</i> -C ₃ H ₇ MgX (excess)	1-Hydroxy-3,9-dimethyl-6,6-di- <i>n</i> -propyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran	63

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₁₈O₄ (<i>cont.</i>)			
1-Acetoxy-3,9-dimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	<i>n</i> -C ₄ H ₉ MgX (excess)	1-Hydroxy-3,9-dimethyl-6,6-di- <i>n</i> -butyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran	63
C₁₇H₂₀O₃			
1-Hydroxy-3- <i>n</i> -propyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3- <i>n</i> -propyl-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (85.6%)	6,63
C₁₇H₂₀O₄			
3- <i>n</i> -Butyl-4,7-dimethyl-5-acetoxycoumarin	CH ₃ MgI	2,2,4,7-Tetramethyl-3- <i>n</i> -butyl-5-hydroxy-1,2-benzopyran	63
4-Methyl-5-acetoxy-7- <i>n</i> -amylcoumarin	CH ₃ MgI (excess)	2,2,4-Trimethyl-5-hydroxy-7- <i>n</i> -amyl-1,2-benzopyran	44
C₁₈H₁₂O₂			
3- α -Naphthylphthalide (5.0 g.)	1-C ₁₀ H ₇ MgBr (8.3 g. C ₁₀ H ₇ Br)	1,3-Di- α -naphthylisobenzofuran (3.5 g., 46%)	46
C₁₈H₂₀O₃N			
3-Methyl-8-isoamyl-10-hydroxy-1,2,3,4-tetrahydropyridino[3,4- <i>c</i>]benzo[<i>e</i>]pyran-5-one (5 g.)	CH ₃ MgI (7.5 ml. CH ₃ I)	3,5,5-Trimethyl-8-isoamyl-10-hydroxy-1,2,3,4-tetrahydropyridino[3,4- <i>c</i>]benzo[<i>e</i>]pyran	10
C₁₈H₂₂O₃			
1-Hydroxy-3- <i>n</i> -amyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3- <i>n</i> -amyl-6,6-dimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (71.5)	8
1-Hydroxy-3- <i>n</i> -butyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3- <i>n</i> -butyl-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (80%)	8,63

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₉H₁₄O₂			
3- <i>o</i> -Tolyl-1,3-naphtho[1.8- <i>cd</i>]-pyrone (4.0 g.)	C ₆ H ₅ CH ₂ MgCl (2.3 g. C ₇ H ₇ Cl)	1-Benzylidene-3- <i>o</i> -tolyl-1,3-naphtho[1.8- <i>cd</i>]-pyran (50%)	55
C₁₉H₂₀O₃			
1-Hydroxy-3- <i>n</i> -amyl-9-methyl-6-dibenzo[<i>b,d</i>]pyrone (3.6 g.)	CH ₃ MgI (8.0 ml. CH ₃ I)	1-Hydroxy-3- <i>n</i> -amyl-6,6,9-trimethyl-6-dibenzo[<i>b,d</i>]pyran (Cannabinol) (2.8 g., 75%) (after MgSO ₄ dehydration)	3
1-Hydroxy-3-diethylmethyl-9-methyl-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3-diethylmethyl-6,6,9-trimethyl-6-dibenzo[<i>b,d</i>]pyran (after MgSO ₄ dehydration)	3
1- <i>n</i> -Amyl-3-hydroxy-9-methyl-6-dibenzo[<i>b,d</i>]pyrone (8.3 g.)	CH ₃ MgI (49.0 g. CH ₃ I)	1- <i>n</i> -Amyl-3-hydroxy-6,6,9-trimethyl-6-dibenzo[<i>b,d</i>]pyran	7
2- <i>n</i> -Amyl-3-hydroxy-9-methyl-6-dibenzo[<i>b,d</i>]pyrone (6.9 g.)	CH ₃ MgI (24.0 ml. CH ₃ I)	2- <i>n</i> -Amyl-3-hydroxy-6,6,9-trimethyl-6-dibenzo[<i>b,d</i>]pyran (6.0 g., 85%) (after MgSO ₄ dehydration)	4
3-Hydroxy-4- <i>n</i> -amyl-9-methyl-6-dibenzo[<i>b,d</i>]pyrone (1.7 g.)	CH ₃ MgI (9.8 g. CH ₃ I)	3-Hydroxy-4- <i>n</i> -amyl-6,6,9-trimethyl-6-dibenzo[<i>b,d</i>]pyran (1.3 g.) (after MgSO ₄ dehydration)	4
C₁₉H₂₂O₄			
7- <i>n</i> -Amyl-9-acetoxy-2,3-dihydrobenzo[<i>b</i>]cyclopenta[<i>d</i>]pyran-4(1 <i>H</i>)-one	CH ₃ MgI (excess)	4,4-Dimethyl-7- <i>n</i> -amyl-9-hydroxy-1,2,3,4-tetrahydrobenzo[<i>b</i>]cyclopenta[<i>d</i>]pyran	44
C₁₉H₂₄O₃			
1-Hydroxy-3- <i>n</i> -amyl-8-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3- <i>n</i> -amyl-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (80%)	8,63

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₉H₂₄O₃ (cont.)			
DL-1-Hydroxy-3- <i>n</i> -amyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone* (9 g.)	CH ₃ MgI (22.5 g. CH ₃ I)	DL-1-Hydroxy-3- <i>n</i> -amyl-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (Tetrahydrocannabinol) (7.3 g., 78%)	2
1-Hydroxy-3- <i>n</i> -amyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	C ₂ H ₅ MgBr (excess)	1-Hydroxy-3- <i>n</i> -amyl-6,6-diethyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (77%)	8
1-Hydroxy-3- <i>n</i> -amyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	<i>n</i> -C ₃ H ₇ MgBr (excess)	1-Hydroxy-3- <i>n</i> -amyl-6,6-di- <i>n</i> -propyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (77.5%)	8
1-Hydroxy-3- <i>n</i> -amyl-10-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3- <i>n</i> -amyl-6,6,10-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (71%)	8,63
1-Hydroxy-3- <i>i</i> -amyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3- <i>i</i> -amyl-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran	63
1-Hydroxy-3-(1-methylbutyl)-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (12 equiv.)	1-Hydroxy-3-(1-methylbutyl)-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (73%)	5
C₂₀H₁₄O₂			
3,3-Diphenylphthalide [†] (20 g.)	C ₆ H ₅ MgBr (30 g. C ₆ H ₅ Br)	1,2-[HO(C ₆ H ₅) ₂ C] ₂ C ₆ H ₄ (ca. 18 g.)	45,64
3,3-Diphenylphthalide [†]	4-CH ₃ C ₆ H ₄ MgBr	1- <i>p</i> -Tolyl-3,3-diphenylphthalan-1-ol	25

* The D and L compounds were treated separately in a similar manner by Adams, Smith, and Loewe, *J. Am. Chem. Soc.*, 64, 2087-9 (1942), with similar results.

[†] Phthalophenone.

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₀H₂₂O₃			
1-Methoxy-4- <i>n</i> -amyl-9-methyl-6-dibenzo[<i>b,d</i>]pyrone (2.1 g.)	CH ₃ MgI (8.0 ml. CH ₃ I)	1-Methoxy-4- <i>n</i> -amyl-6,6,9-trimethyl-6-dibenzo[<i>b,d</i>]pyran (1.85 g., 84%) (after MgSO ₄ dehydration)	1
1-Methoxy-4- <i>n</i> -amyl-9-methyl-6-dibenzo[<i>b,d</i>]pyrone (1.36 g.)	CH ₃ MgI (2.60 ml. CH ₃ I)	2-(α -Methyl- α -hydroxyethyl)-5-methyl-2'-hydroxy-3'- <i>n</i> -amyl-6'-methoxybiphenyl (1.2 g., 80%)	1
C₂₀H₂₄O₄			
1-Acetoxy-3- <i>n</i> -amyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3- <i>n</i> -amyl-6,6-dimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran	44
C₂₀H₂₆O₃			
1-Hydroxy-3- <i>n</i> -hexyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3- <i>n</i> -hexyl-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (80.7%)	6, 63
1-Hydroxy-3- <i>i</i> -hexyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3- <i>i</i> -hexyl-6,6,9-trimethyl-7,8,9,10-tetrahydro[<i>b,d</i>]pyran	63
1-Hydroxy-3-(1-methylpentyl)-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (12 equiv.)	1-Hydroxy-3-(1-methylpentyl)-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (70%)	5
1-Hydroxy-3-(1-ethylbutyl)-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (12 equiv.)	1-Hydroxy-3-(1-ethylbutyl)-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (76%)	5
C₂₁H₂₆O₄			
1-Acetoxy-3- <i>n</i> -amyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3- <i>n</i> -amyl-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (Tetrahydrocannabinol)	21

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₁H₂₆O₄ (cont.)			
1-Acetoxy-3- <i>n</i> -amyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	C ₂ H ₅ MgBr (excess)	1-Hydroxy-3- <i>n</i> -amyl-6,6-diethyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran	63
2-Acetoxy-3- <i>n</i> -amyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone (0.25 g.)	CH ₃ MgI (0.25 g. Mg)	2-Hydroxy-3- <i>n</i> -amyl-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran	44
2-Acetoxy-5- <i>n</i> -amyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	2-Hydroxy-5- <i>n</i> -amyl-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran	20
C₂₁H₂₈O₃			
1-Hydroxy-3- <i>n</i> -heptyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3- <i>n</i> -heptyl-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (70%)	6,63
1-Hydroxy-3-(1-methylhexyl)-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (12 equiv.)	1-Hydroxy-3-(1-methylhexyl)-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (74%)	5
C₂₁H₂₈O₄			
3- <i>n</i> -Butyl-4-methyl-5-acetoxy-7- <i>n</i> -amylcoumarin	CH ₃ MgI	2,2,4-Trimethyl-3- <i>n</i> -butyl-5-hydroxy-7- <i>n</i> -amyl-1,2-benzopyran	63
C₂₂H₁₄O₂			
3- α -Naphthyl-1,3-naphtho-[1.8- <i>cd</i>]pyrone	C ₆ H ₅ CH ₂ MgCl (2.3 g. C ₇ H ₇ Cl)	1-Benzylidene-3- α -naphthyl-1,3-naphtho-[1.8- <i>cd</i>]pyran (60%)	55
C₂₂H₃₀O₃			
1-Hydroxy-3- <i>n</i> -octyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (excess)	1-Hydroxy-3- <i>n</i> -octyl-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (93.2%)	6

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₂H₃₀O₃ (cont.)			
1-Hydroxy-3-(1-methylheptyl)-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (12 equiv.)	1-Hydroxy-3-(1-methylheptyl)-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (56%)	5
1-Hydroxy-3-(1- <i>n</i> -propylpentyl)-9-methyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI (12 equiv.)	1-Hydroxy-3-(1- <i>n</i> -propylpentyl)-6,6,9-trimethyl-7,8,9,10-tetrahydro-6-dibenzo[<i>b,d</i>]pyran (60%)	5
C₂₄H₁₆O₂			
3,3-Diphenyl-1,3-naphtho[1.8- <i>cd</i>]pyrone	C ₂ H ₅ MgBr (2-fold excess)	1-Ethyl-3,3-diphenyl-1,3-naphtho[1.8- <i>cd</i>]pyran-1-ol	19
3,3-Diphenyl-1,3-naphtho[1.8- <i>cd</i>]pyrone (10 g.)	<i>i</i> -C ₃ H ₇ MgBr (2-fold excess)	1-Isopropyl-3,3-diphenyl-1,3-naphtho[1.8- <i>cd</i>]pyran-1-ol	19
3,3-Diphenyl-1,3-naphtho[1.8- <i>cd</i>]pyrone	<i>n</i> -C ₄ H ₉ MgBr (2-fold excess)	1- <i>n</i> -Butyl-3,3-diphenyl-1,3-naphtho[1.8- <i>cd</i>]pyran-1-ol	19
3,3-Diphenyl-1,3-naphtho[1.8- <i>cd</i>]pyrone	<i>s</i> -C ₄ H ₉ MgBr (2-fold excess)	1- <i>s</i> -Butyl-3,3-diphenyl-1,3-naphtho[1.8- <i>cd</i>]pyran-1-ol	19
C₂₆H₁₈O₂			
7,7-Diphenyldiphenide	C ₆ H ₅ MgBr	5-Benzoyl-9,9-diphenylfluorene	52
C₂₆H₂₆O₃			
1- α -Toloxyl-2- <i>n</i> -amyl-9-methyl-6-dibenzo[<i>b,d</i>]pyrone (1.5 g.)	CH ₃ MgI (6.0 ml. CH ₃ I)	2-(α -Methyl- α -hydroxyethyl)-5-methyl-2'-hydroxy-5'- <i>n</i> -amyl-6'- α -toloxybiphenyl (1.2 g., 74%)	1
1- α -Toloxyl-4- <i>n</i> -amyl-9-methyl-6-dibenzo[<i>b,d</i>]pyrone (1 g.)	CH ₃ MgI (3 ml. CH ₃ I)	1- α -Toloxyl-4- <i>n</i> -amyl-6,6,9-trimethyl-6-dibenzo[<i>b,d</i>]pyran (0.9 g., 85%) (after MgSO ₄ dehydration)	1

TABLE VIII-IV (Continued)

<u>Lactone or Lactide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₆H₂₆O₃ (<i>cont.</i>)			
1- α -Toloxyl-4- <i>n</i> -amyl-9-methyl-6-dibenzo[<i>b,d</i>]pyrone	CH ₃ MgI	2-(α -Methyl- α -hydroxyethyl)-5-methyl-2'-hydroxy-3'- <i>n</i> -amyl-6'- α -toloxybiphenyl	1
C₂₆H₄₀O₄			
3(β)-Acetoxy-17-hydroxy-allocholanil acid lactone-(24 \rightarrow 17)	CH ₃ MgI	3(β), 17, 24-Trihydroxy-24, 24-dimethyl-allocholanil	12

REFERENCES FOR TABLE VIII-IV

- (1) Adams and Baker, *J. Am. Chem. Soc.*, 62, 2208-15 (1940).
- (2) Adams and Baker, *J. Am. Chem. Soc.*, 62, 2405-8 (1940).
- (3) Adams, Baker, and Wearn, *J. Am. Chem. Soc.*, 62, 2204-7 (1940).
- (4) Adams, Cain, and Baker, *J. Am. Chem. Soc.*, 62, 2201-4 (1940).
- (5) Adams, Chen, and Loewe, *J. Am. Chem. Soc.*, 67, 1534-7 (1945).
- (6) Adams, Loewe, Jelinek, and Wolff, *J. Am. Chem. Soc.*, 63, 1971-3 (1941).
- (7) Adams, Pease, Clark, and Baker, *J. Am. Chem. Soc.*, 62, 2197-200 (1940).
- (8) Adams, Smith, and Loewe, *J. Am. Chem. Soc.*, 63, 1973-6 (1941).
- (9) Allen, Gates, and Van Allan, *Organic Syntheses*, 27, 31-2 (1947).
- (10) Anker and Cook, *J. Chem. Soc.*, 1946, 58-60.
- (11) Barnett, Cook, and Nixon, *J. Chem. Soc.*, 1927, 504-12.
- (12) Billeter and Miescher, *Helv. Chim. Acta*, 32, 564-73 (1949).
- (13) Decker and Felser, *Ber.*, 41, 3755-7 (1908).
- (14) Decker and von Fellenberg, *Ann.*, 356, 281-342 (1907).
- (15) Freudenberg, Todd, and Seidler, *Ann.*, 501, 199-219 (1933).
- (16) Fuson, Armstrong, Fisher, Rabjohn, Ulliyot, and Wallace, *J. Am. Chem. Soc.*, 68, 343 (1946).
- (17) Fuson and Rachlin, *J. Am. Chem. Soc.*, 64, 1567-71 (1942).
- (18) Geissman, *J. Am. Chem. Soc.*, 62, 1363-7 (1940).
- (19) Geissman and Morris, *J. Am. Chem. Soc.*, 63, 1111-4 (1941).
- (20) Ghosh, Pascal, and Todd, *J. Chem. Soc.*, 1940, 1118-21.
- (21) Ghosh, Todd, and Wilkinson, *J. Chem. Soc.*, 1940, 1121-5.
- (22) Gresham, Jansen, Shaver, and Bankert, *J. Am. Chem. Soc.*, 71, 2807-8 (1949).
- (23) Guyot and Catel, *Compt. rend.*, 140, 1348-50 (1905); *Chem. Zentr.*, 1905,II, 137.
- (24) Guyot and Catel, *Bull. soc. chim.*, [3], 35, 1124-35 (1906).
- (25) Guyot and Vallette, *Ann. chim.*, [8], 23, 363-97 (1911).
- (26) Heilbron and Hill, *J. Chem. Soc.*, 1927, 2005-13.
- (27) Heilbron and Zaki, *J. Chem. Soc.*, 1926, 1902-6.
- (28) Henry, *Compt. rend.*, 143, 1221-5 (1906); *Chem. Zentr.*, 1907,I, 708.
- (29) Houben, *Ber.*, 37, 489-502 (1904).
- (30) Kohn, *Monatsh.*, 34, 1729-40 (1913).
- (31) Kohn and Ostersetzer, *Monatsh.*, 37, 37-51 (1916).
- (32) Losanitsch, *Compt. rend.*, 153, 390-2 (1911); *Chem. Zentr.*, 1911,II, 1118.
- (33) Lothrop and Goodwin, *J. Am. Chem. Soc.*, 65, 363-7 (1943).
- (34) Löwenbein, Pongrácz, and Spiess, *Ber.*, 57B, 1517-26 (1924).
- (35) Löwenbein and Rosenbaum, *Ann.*, 448, 223-48 (1926).
- (36) Ludwig, *Ber.*, 40, 3060-5 (1907).
- (37) McPhee and Ball, *J. Am. Chem. Soc.*, 66, 1636-40 (1944).
- (38) Mermod and Simonis, *Ber.*, 41, 982-5 (1908).
- (39) Neuberg and Ohle, *Biochem. Z.*, 127, 327-39 (1922); *Chem. Zentr.*, 1922,I, 1333.
- (40) Paal and Hörnstein, *Ber.*, 39, 1361-4 (1906).
- (41) Paal and Kinscher, *Ber.*, 44, 1343-55 (1911).
- (42) Paal, Küster, and Roth, *Ber.*, 49, 1583-97 (1916).
- (43) Paal and Weidenkaff, *Ber.*, 39, 2827-33 (1906).
- (44) Russell, Todd, Wilkinson, Macdonald, and Wolfe, *J. Chem. Soc.*, 1941, 169-72.
- (45) Schlenk and Brauns, *Ber.*, 48 716-28 (1915).
- (46) Seer and Dischendorfer, *Monatsh.*, 34, 1493-502 (1914).
- (47) Seidel, *Ber.*, 61B, 2267-76 (1928).
- (48) Shriner and Sharp, *J. Org. Chem.*, 4, 575-82 (1939).

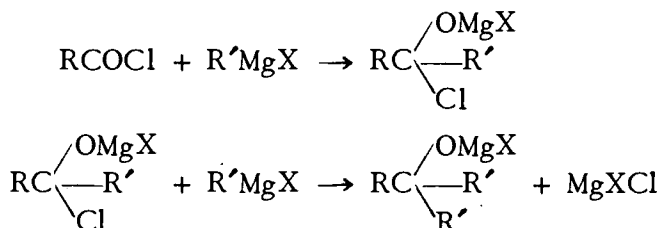
- (49) Smith and Ruoff, *J. Am. Chem. Soc.*, 62, 145-8 (1940).
- (50) Smith, Ungnade, Hoehn, and Wawzonek, *J. Org. Chem.*, 4, 304-10 (1939).
- (51) Smith, Ungnade, and Prichard, *J. Org. Chem.*, 4, 358-62 (1939).
- (52) Ssergejew, *J. Russ. Phys.-Chem. Soc.*, 61, 1421-49 (1929); *Chem. Zentr.*, 1930,II, 391.
- (53) Stiller, Kereszeteszy, and Finkelstein, *J. Am. Chem. Soc.*, 62, 1779-84 (1940).
- (54) Weiss and Alberti, *Monatsh.*, 59, 220-7 (1932).
- (55) Weiss and Fastmann, *Monatsh.*, 47, 727-32 (1926).
- (56) Weiss, Grobstein, and Sauermann, *Ber.*, 59B, 301-6 (1926).
- (57) Weiss and Sauermann, *Ber.*, 58B, 2736-40 (1925).
- (58) Weiss and Sonnenschein, *Ber.*, 58B, 1043-7 (1925).
- (59) Weizmann and Bergmann, *J. Am. Chem. Soc.*, 60, 2647-50 (1938).
- (60) Willstätter and Schmidt, *Ber.*, 57B, 1945-50 (1924).
- (61) Willstätter, Zechmeister, and Kindler, *Ber.*, 57B, 1938-44 (1924).
- (62) John, Günther, and Schmeil, *Ber.*, 71B, 2637-49 (1938).
- (63) Russell, Todd, Wilkinson, Macdonald, and Woolfe, *J. Chem. Soc.*, 1941, 826-9.
- (64) Guyot and Catel, *Bull. soc. chim.*, [3], 35, 551-62 (1906).
- (65) Guyot and Catel, *Bull. soc. chim.*, [3], 35, 567-71 (1906).
- (66) Shriner, Johnston, and Kaslow, *J. Org. Chem.*, 14, 204-9 (1949).

CHAPTER IX

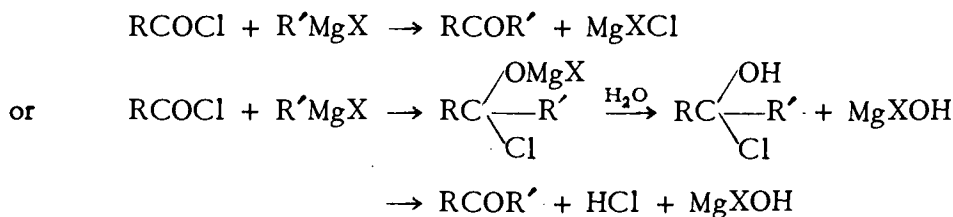
Reactions of Grignard Reagents with Carbonyl Halides

SPECULATIONS ON THE ("NORMAL") REACTION MECHANISM

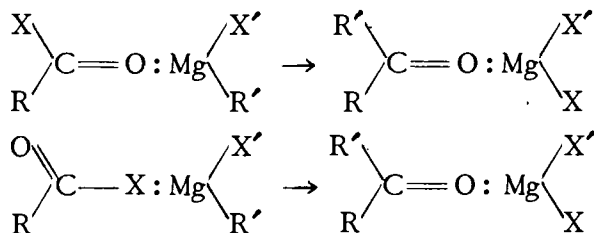
The reaction of an acid chloride of the type RCOCl with two equivalents of a Grignard reagent to yield a tertiary alcohol was first reported by Tissier and Grignard,¹ who proposed a two-stage reaction mechanism analogous to that previously suggested by Grignard² for the similar reaction of a carboxylic ester with a Grignard reagent (see Chapter VIII).



Courtot³ has suggested the alternatives:



These, of course, do not describe exhaustively the reaction mechanism possibilities. Either of Courtot's alternatives might involve the initial formation of a Werner complex, presumably through the carbonyl oxygen atom, but conceivably, in the first case at least, through the acyl halogen atom. A Werner complex of either kind might then rearrange to form ketone and magnesium halide.



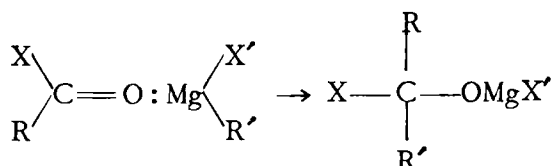
¹Tissier and Grignard, *Compt. rend.*, 132, 683-5 (1901); *J. Chem. Soc.*, 80,1, 316 (1901); *Chem. Zentr.*, 1901,1, 930.

²Grignard, *Compt. rend.*, 132, 336-8 (1901); *J. Chem. Soc.*, 80,1, 250 (1901); *Ann. chim.*, [7], 24, 433-90 (1901).

³Courtot, "Le magnésium en chimie organique," Nancy, 1926, p. 191.

In either case the reaction would be second-order, and either the first step (complex formation) or the second step (rearrangement) might be rate-determining.

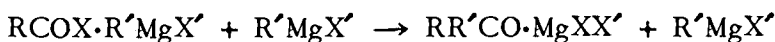
Courtot's second alternative would be most likely to take place through Werner complex formation at the carbonyl oxygen atom and subsequent rearrangement.



In this case also the reaction would be second-order, and either complex formation or complex rearrangement might be the rate-determining step.

It may be noted in passing that the persistence of a derivative of the type postulated seems highly improbable. Even if a rearrangement of this type took place in preference to one of the type previously discussed, it would almost certainly be followed by further rearrangement (either monomolecular or bimolecular to form a ketone-magnesium halide complex.

There remains for consideration the possibility that the reaction is in fact third-order, requiring for completion the reaction of a second molecule of Grignard reagent with a Werner or some other type of intermediate complex.

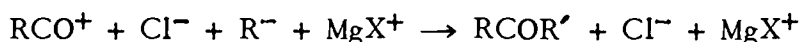


Unfortunately, the rapidity with which aryl halides and Grignard reagents interact discourages attempts at investigation of the reaction kinetics by the classical experimental methods. Moreover, the probability of further reaction of the initial product with excess Grignard reagent eliminates the possibility of applying one of the routine checks on reaction order (except in the cases of "hindered" acyl halides, which are not necessarily typical). However, the fact that ketone may be formed by the slow addition of Grignard reagent solution to an excess of acyl halide solution suggests that the reaction is not third-order in the sense here implied.

Commenting upon the very slow reaction between methylmagnesium chloride and the supposedly "hindered" 2,4,6-trichlorobenzoyl chloride, Fuson⁴ says: "This reaction between 2,4,6-trichlorobenzoyl chloride and methylmagnesium chloride is interesting because it shows the effect of steric hindrance on a reaction which may be either additive or metathetical. In view of the fact that reactions of the former type are generally much more greatly affected by steric factors than are those known to be of the latter type, the results here reported suggest that the primary reaction between RMgX and an acid chloride is one of addition."

⁴Fuson, Bertetti, and Ross, *J. Am. Chem. Soc.*, 54, 4380-3 (footnote, p. 4381) (1932).

If by a "metathetical"* reaction is meant one of the type,



the improbability of such a reaction in a medium of the low dielectric constant of ether is obvious. If anything else is meant the distinction between a metathetical reaction and an additive reaction becomes rather equivocal.

It is doubtful that the formation of a Werner complex of either of the types here suggested would be greatly inhibited sterically by the *ortho* chlorine atoms of 2,4,6-trichlorobenzoyl chloride. However, the subsequent rearrangement, involving addition of the Grignard reagent organic ion to the carbonyl carbon atom would be subject to steric hindrance. If the 2,4,6-trichlorobenzoyl chloride reaction may be regarded as typical it would seem that rearrangement rather than complex formation must be the rate-determining step. According to Swain⁵ this is probably the case in nitrile reactions (see section on Reaction Mechanism in Chapter X.)

By means of competitive reactions in the presence of acetophenone and benzophenone, Entemann and Johnson⁶ have determined that the order of reactivity toward phenylmagnesium bromide of the benzoyl halides is the reverse of that encountered in hydrolytic,⁷ alcoholic,⁸ phenolytic,⁹ and Friedel-Crafts¹⁰ reactions. That is, the fluoride is more reactive than the chloride, which is, in turn, more reactive than the bromide.

Without supporting argument or elucidative discussion, they state: "The order of activity of the three acid halides, benzoyl fluoride, chloride, and bromide, is of particular interest because of its bearing upon the mechanism of the action of Grignard reagents upon acid derivatives. Either one of two reactions may occur in the initial stage of the reaction: addition to the carbonyl group (I) or direct replacement of the halogen atom (II). If the reaction follows the second mechanism, one would expect the acid fluoride to be the least reactive of the halides. Since the acid fluoride is actually found to be the most reactive, it is obvious that the reaction occurs through addition to the carbonyl group and not through a metathetical reaction of the halogen atom."

This line of reasoning depends upon a gratuitous assumption concerning the mechanism of the rate-determining step of the "metathetical" reaction. An *ion-ion* exchange might be expected to give rise to the

*Actually, the term metathetical is primarily stoichiometric in significance. It can be regarded as having mechanistic connotations only in so far as it eliminates certain reaction mechanisms from consideration.

⁵Swain, *J. Am. Chem. Soc.*, 69, 2306-9 (1947).

⁶Entemann and Johnson, *J. Am. Chem. Soc.*, 55, 2900-3 (1933).

⁷Staudinger and Anthes, *Ber.*, 46, 1417-26 (1913); Karve and Dole, *J. Univ. Bombay*, 7, Pt. 3, 108-25 (1938); *Chem. Abstr.*, 33, 5269 (1939).

⁸Dann, Davies, Hambly, Paul, and Semmens, *J. Chem. Soc.*, 1933, 15-21; Leimu, *Ber.*, 70B, 1040-53 (1937).

⁹Bernoulli and St. Goar, *Helv. Chim. Acta*, 9, 730-65 (1926).

¹⁰Calloway, *J. Am. Chem. Soc.*, 59, 1474-9 (1937).

halide reactivity order experimentally observed. For reasons already suggested monomolecular or solvolytic ionization of the reactants as a prelude to reaction appears impossible. Ionic exchange must therefore be preceded by some sort of addition-complex formation, though *not necessarily* by carbonyl double-bond addition. It may or may not be significant in this connection that the order of reactivity of acyl halides toward the organozinc, -cadmium, and -mercury compounds (which do not undergo carbonyl double bond addition, or which do so very slowly indeed) is said to be the reverse of that toward Grignard reagents.¹¹ Even mercuric chloride is known to form complexes with carbonyl compounds.¹²

On the whole it appears most probable that the "normal" reaction includes (1) acyl halide-Grignard reagent Werner complex formation and (2) a rate-determining *ionic* rearrangement of the complex, and that the reaction product is a ketone-magnesium halide Werner complex.

On this basis it may be predicted that, when investigated, the order of reactivity of the acyl halides in the "abnormal" coupling reaction will be found to be the reverse of that established for the "normal" ketone-formation reaction.

PREPARATION OF KETONES BY GRIGNARD-HALIDE INTERACTION

Grignard's two-stage reaction formulation, together with the reported isolation of ketones as products of many carbonyl chloride-Grignard reagent interactions (see Table IX-II), suggests that the first stage of the reaction might be employed as a method of ketone preparation. For that purpose low operating temperatures, reverse addition (*i.e.*, addition of the Grignard reagent to the acid chloride or its solution), and the use of an excess of the acid chloride are obviously indicated. The reaction has indeed been so employed by, among others: Gilman *et al.*,¹³ Helferich and Malkomes,¹⁴ Darzens and Rost,¹⁵ Acree,¹⁶ Schmidlin,¹⁷ Karrer,¹⁸ and Whitmore and Badertscher¹⁹ (see Table IX-II).

Often, however, the reactivity differential between the acid chloride chlorine and the ketone carbonyl group either favors the carbonyl group or is too small to make this a satisfactory method of ketone preparation. Even in favorable cases and under optimum experimental conditions the yields are usually indifferent (*i.e.*, of the order of 40-60 percent).

¹¹Gilman, "Organic Chemistry," 2nd ed., Chapter 5, pp. 501-2, 1943.

¹²See, *e.g.*: Marini-Bettolo and Paolini, *Gazz. chim. ital.*, 75, 78-86 (1945); *Chem. Abstr.*, 41, 3444 (1947).

¹³Gilman, Fothergill, and Parker, *Rec. trav. chim.*, 48, 748-51 (1929).

¹⁴Helferich and Malkomes, *Ber.*, 55B, 702-8 (1922).

¹⁵Darzens and Rost, *Compt. rend.*, 153, 772-5 (1911); *Chem. Zentr.*, 1911, 11, 1860.

¹⁶Acree, *Ber.*, 37, 625-8 (1904).

¹⁷Schmidlin and Massini, *Ber.*, 42, 2377-92 (1909); Schmidlin, *ibid.*, 43, 1137-44 (1910).

¹⁸Karrer, *Ber.*, 50, 1499-508 (1917).

¹⁹Whitmore and Badertscher, *J. Am. Chem. Soc.*, 55, 1559-67 (1933).

As good, or better, yields might reasonably be expected in the special cases in which the intermediate ketone is both readily enolizable and relatively inert toward enolate addition. The reaction of phenylmesityl-acetyl chloride with mesitylmagnesium bromide, reported by Fuson *et al.*,²⁰ probably represents such a case. These authors, using equimolecular quantities of acid chloride and Grignard reagent, and employing reverse addition, reported a 34 percent yield of ketone, but with recovery of 27.5 percent acid chloride (as the acid). Paradoxically, the normal order of addition of acid chloride to an excess of Grignard reagent (to supply the loss through enolization) should improve the yield of ketone. Upon slow addition of 2,4,6-tribromobenzoyl chloride to 2.2 equivalents of methylmagnesium iodide,* Fuson²¹ obtained a 46 percent yield of the acetophenone derivative.

It may be noted in passing that, for reasons not altogether obvious, the pyrrol and indolyl Grignard reagents appear to have a tendency to terminate reaction with acyl halides (as with esters, *q.v.*) at the first stage, forming ketones.

When applicable, however, the organozinc halides or the diorgano-cadmium compounds give superior results.

KETONE PREPARATION WITH THE AID OF ZINC AND CADMIUM SALTS

Although this topic does not fall strictly within the announced scope of the present work, the preparations concerned are (from the standpoint of procedure) essentially Grignard preparations,[†] and they have now been shown to constitute so useful a supplement to the ordinary Grignard reactions that they are included for the convenience of the reader.

The use of organocadmium compounds for the preparation of ketones from acid chlorides was first recommended by Gilman and Nelson.²² Optimum experimental conditions have been investigated by Cason,²³ who has also reviewed the field.²⁴

The advantages claimed for the use of organocadmium compounds are: that they are readily prepared from Grignard reagents and the relatively economical, nonhygroscopic cadmium chloride; that the preparation and subsequent reaction can be carried out in ether solution (although ben-

²⁰Fuson, Armstrong, Kneisley and Shenk, *J. Am. Chem. Soc.*, 66, 1414-6 (1944).

*For this purpose the bromide would be preferable because it has little or no "coupling" action.

²¹Fuson, Van Campen, and Wolf, *J. Am. Chem. Soc.*, 60, 2269-72 (1938).

[†]Organocadmium compounds may be prepared from organolithium compounds as well as from Grignard reagents, but there is no advantage to be derived from the use of the lithium compounds except in the relatively rare cases in which the Grignard reagent can be prepared only with great difficulty or in very poor yield.

²²Gilman and Nelson, *Rec. trav. chim.*, 55, 518-30 (1936).

²³Cason, *J. Am. Chem. Soc.*, 68, 2078-81 (1946).

²⁴Cason, *Chem. Revs.*, 40, 15-32 (1947).

zene, or toluene, is the preferred solvent for acid chloride reactions); that, although they react readily with acid chlorides and acid anhydrides, they are very unreactive toward other functional groups (including the carbonyl) that react more or less readily with Grignard reagents. The R_2Cd and $RCdX$ compounds appear to be equally satisfactory but the former are most often used as requiring less cadmium chloride.

The organozinc compounds are similar in chemical properties to the corresponding organocadmium compounds but, notwithstanding the recommendation of Blaise,²⁵ who gives no experimental details, are alleged to be comparatively disadvantageous because of: the greater difficulty of preparation; the undesirability of using ether as a solvent in acid chloride reactions (because of ether cleavage and ester formation); and the greater reactivity of the zinc compounds, particularly toward carbonyl groups. The earlier investigators²⁶ employed organozinc iodides prepared by the action of organic iodides on zinc or a zinc-copper couple. It is possible, however, to affect the preparation by a method analogous to that commonly employed for the preparation of organocadmium compounds, namely, by the addition of anhydrous zinc chloride to a Grignard reagent solution, a method which has been used with good success by Jones²⁷ and others.

In general the organomagnesium iodides are unsatisfactory for the preparation of organocadmium compounds and their subsequent reaction with acid chlorides (Gilman and Nelson, *loc. cit.*;²² Cason, *loc. cit.*^{23,24}), and Cason reports that in general the bromides give better yields than the corresponding chlorides. Secondary alkylmagnesium halides with the possible exception of isopropyl, do not give satisfactory results, even at low temperatures.

The experimental procedure recommended by Cason (*loc. cit.*²³) is described in an illustrative example as follows. "A Grignard reagent was prepared from excess methyl bromide and 4.9 g. (0.2 mole) of magnesium in 100 ml. of ether. To the ice-cold solution was added, during five minutes, 19.6 g. of cadmium chloride; then the mixture was stirred under reflux until a negative Gilman test was obtained (fifteen to twenty minutes). Ether was distilled rapidly from the stirred mixture by heating on a steam-bath until distillation became slow and a nearly dry residue remained. After addition of 65 ml. of benzene, distillation was continued until an additional 25 ml. of distillate had been collected. There was then added 120 ml. of benzene, the stirred solution was heated to boiling and there was added without external heating 24.9 g. (0.1 mole) of ω -carbethoxynonyl chloride in 30 ml. of benzene as rapidly (two minutes) as

²⁵Blaise, *Bull. soc. chim.*, [4], 9, I-XXVI (1911).

²⁶See, for example: Blaise, *loc. cit.*²⁵; Mauthner, *J. prakt. Chem.*, [2], 103, 391-6 (1921); Michael, *J. Am. Chem. Soc.*, 41, 393-424 (1919); Ruzicka and Stoll, *Helv. Chim. Acta*, 10, 692-4 (1927).

²⁷Jones, *J. Am. Chem. Soc.*, 69, 2350-4 (1947).

consistent with control of the exothermic reaction. Heating under reflux with stirring was continued for ten minutes, at which time the stirrer was stopped by the mass of precipitate. Ten minutes later the reaction was worked up as previously described;²⁸ yield of ethyl 10-ketohendecanoate, b.p. 147.5–149.5° (4 mm.), 19.4 g. (83.7 percent). The distillation residue weighed 2.7 g.”

An analogous preparation with the aid of zinc chloride is described by Jones (*loc. cit.*²⁷) as follows. “A solution of 110 g. (0.33 mole) of octadecyl bromide, b.p. 182–183° (2.5 mm.), m.p. 28.5°; in 400 ml. of anhydrous ether was added in the usual way to 15 g. of magnesium turnings in 100 ml. of ether. Titration of the resulting Grignard solution showed it to be 0.58 molar (about 85 percent yield).

“In a 1-liter, three-necked flask provided with a stirrer, reflux condenser and dropping funnel, were placed 38 g. (0.27 mole) of freshly-fused, powdered zinc chloride and 100 ml. of anhydrous ether. To this was added (by means of a 100-ml. pipet) 470 ml. (0.27 mole) of the octadecylmagnesium bromide solution. After the initial reaction, the mixture was stirred and heated for two hours during which time ether was allowed to distill until the volume had been reduced to about 300 ml. With continued stirring a solution of 54 g. (0.20 mole) of ω -carbethoxyundecanoyl chloride in 100 ml. of dry benzene was added during fifteen minutes. The viscous mixture was stirred and heated under reflux for three hours and then hydrolyzed with 500 ml. of 2 *N* hydrochloric acid solution. One liter of hot benzene was added. The aqueous layer was separated, and the warm benzene solution was washed with 400 ml. of hot dilute hydrochloric acid and two 400-ml. portions of hot (80–70°) water. The benzene solution was evaporated to about 100 ml., treated with 30 ml. of 12 *N* sodium hydroxide solution and 50 ml. of ethanol and digested on the steam-bath for two hours during which time most of the remaining solvent evaporated. The resulting white solid was thoroughly washed by suspension in two 500-ml. portions of warm benzene, air-dried, and then washed by suspension in two 500-ml. portions of water. Finally it was suspended in 500 ml. of 2 *N* hydrochloric acid solution and digested on the steam-bath for two hours. The 12-ketotriacontanoic acid was collected, air-dried and recrystallized from benzene.” [Yield, 79 percent.]

Data on some representative examples of preparations of this kind are collected in Table IX-I.

²⁸Cason and Prout, *J. Am. Chem. Soc.*, 66, 46–50 (1944). “The organometallic complex was decomposed with ice and sulfuric acid, and the water layer was separated and extracted twice with benzene. The benzene extracts were washed with water, 5 percent sodium carbonate solution, water, and saturated sodium chloride solution, then filtered through a layer of anhydrous sodium sulfate. After the solvent had been flashed off, the residue was distilled through an 18-inch Podbielniak-type column.”

TABLE IX-I
PREPARATION OF KETONES FROM ACID HALIDES WITH THE AID OF CADMIUM OR ZINC SALTS

<u>Halide</u>	<u>RMgX</u>	<u>Cd or Zn Salt</u>	<u>% Yield Ketone</u>	<u>Ref.</u>
C₂H₂OCl₂				
ClCH ₂ COCl (0.78 mole)	<i>n</i> -C ₄ H ₉ MgBr (0.775 mole Mg)	CdCl ₂ (0.44 mole)	26.0	1
ClCH ₂ COCl (0.28 mole)	<i>n</i> -C ₄ H ₉ MgBr (0.35 mole C ₄ H ₉ Br)	CdCl ₂ (0.188 mole)	50.8	2
ClCH ₂ COCl	<i>n</i> -C ₅ H ₂₉ MgBr	CdCl ₂	24.0	1
ClCH ₂ COCl	<i>n</i> -C ₁₂ H ₂₅ MgBr	CdCl ₂	18.0	1
ClCH ₂ COCl (0.05 mole)	<i>n</i> -C ₁₄ H ₂₉ MgBr (0.063 mole C ₁₄ H ₂₉ Br)	CdCl ₂	33.0	2
ClCH ₂ COCl	<i>n</i> -C ₁₄ H ₂₀ MgBr	CdCl ₂	14.5	1
C₂H₃OCl				
CH ₃ COCl	C ₂ H ₅ MgBr	CdCl ₂	46.0	3
CH ₃ COCl	C ₂ H ₃ MgBr	CdBr ₂	50.0	3
CH ₃ COCl	<i>n</i> -C ₄ H ₉ MgBr	CdCl ₂	74.0	3
CH ₃ COCl	<i>t</i> -C ₄ H ₉ MgBr	CdBr ₂	17.0	3
CH ₃ COCl	C ₆ H ₅ MgBr	CdCl ₂	83.0	3
CH ₃ COCl	C ₆ H ₅ MgBr	CdBr ₂	61.0	3
CH ₃ COCl	C ₆ H ₅ CH ₂ MgCl	CdCl ₂	18.0	3
C₃H₄OCl₂				
CH ₃ CHClCOCl (0.173 mole)	<i>n</i> -C ₄ H ₉ MgBr (0.216 mole C ₄ H ₉ Br)	CdCl ₂	42.7	2
CH ₃ CHClCOCl (15.4 g.)	<i>n</i> -C ₁₂ H ₂₅ MgBr (33.1 g. C ₁₂ H ₂₅ Br)	CdCl ₂	13.0, crude	1
C₃H₅OCl				
C ₂ H ₅ COCl	C ₆ H ₅ MgBr	CdCl ₂	76.0	3
C ₂ H ₅ COCl (14.8 g.)	C ₆ H ₅ MgBr (32.4 g. C ₆ H ₅ Br)	CdCl ₂ (19.5 g.)	80.8	2

TABLE IX-1 (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Cd or Zn Salt</u>	<u>% Yield Ketone</u>	<u>Ref.</u>
C₄H₇OCl				
<i>n</i> -C ₃ H ₇ COCl	<i>i</i> -C ₃ H ₇ MgBr	CdBr ₂	60.0	3
C₅H₃O₂Cl				
2-Furoyl chloride	C ₂ H ₃ MgBr	CdCl ₂	61.0	3
C₅H₇O₃Cl				
H ₃ CO ₂ CCH ₂ CH ₂ COCl	<i>n</i> -C ₄ H ₉ MgCl	CdCl ₂	62.8	2
H ₃ CO ₂ CCH ₂ CH ₂ COCl	<i>n</i> -C ₄ H ₉ MgBr	CdCl ₂	76.6	2
H ₃ CO ₂ CCH ₂ CH ₂ COCl	<i>n</i> -C ₄ H ₉ MgI	CdCl ₂	44.7	2
H ₃ CO ₂ CCH ₂ CH ₂ COCl (0.16 mole)	<i>i</i> -C ₅ H ₁₁ MgBr (0.2 mole C ₅ H ₁₁ Br)	CdCl ₂ (0.17 mole)	78.7	2,4,5
H ₃ CO ₂ CCH ₂ CH ₂ COCl (0.8 mole)	<i>i</i> -C ₅ H ₁₁ MgBr (1.0 mole C ₅ H ₁₁ Br)	CdCl ₂ (0.535 mole)	73-75	6
H ₃ CO ₂ CCH ₂ CH ₂ COCl	CH ₃ (C ₂ H ₅)CHCH ₂ MgBr	CdCl ₂	60.0	5
H ₃ CO ₂ CCH ₂ CH ₂ COCl (33.8 g.)	CH ₃ (<i>n</i> -C ₃ H ₇)CHMgBr (0.3 mole C ₅ H ₁₁ Br)	CdCl ₂ (29.3 g.)	21.5	5,2
C₆H₃OClBr				
5-Bromonicotinyl chloride	CH ₃ MgBr	CdCl ₂	25.0	7
C₆H₄OClN				
Nicotinyl chloride (70.0 g., 0.494 mole)	<i>n</i> -C ₃ H ₇ MgBr (73.8 g., 0.60 mole C ₃ H ₇ Br)	CdCl ₂ (55.0 g., 0.30 mole)	30.0	38
C₆H₅OClS				
2-Methyl-3-thiophenecarbonyl chloride (62.4 g.)	CH ₃ MgI (11.40 g. CH ₃ I)	CdCl ₂ (8.25 g.)	49.0	36

TABLE IX-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Cd or Zn Salt</u>	<u>% Yield Ketone</u>	<u>Ref.</u>
C₆H₅O₃Cl				
H ₃ CO ₂ C(CH ₂) ₃ COCl	<i>n</i> -C ₁₀ H ₂₁ C*H ₂ MgBr	CdCl ₂	47.5	35
C₇H₅OCl				
C ₆ H ₅ COCl	CH ₃ MgBr	CdCl ₂	85.0	3
C ₆ H ₅ COCl	C ₂ H ₅ MgBr	CdCl ₂	50.0	3
C ₆ H ₅ COCl (0.21 mole)	C ₂ H ₅ MgBr (0.3 mole C ₂ H ₅ Br)	CdCl ₂	84.4	2
C ₆ H ₅ COCl	C ₆ H ₅ MgBr	CdCl ₂	57.0	3
C₇H₁₁O₃Cl				
H ₃ CO ₂ C(CH ₂) ₄ COCl (130 g.)	<i>i</i> -C ₅ H ₁₁ MgBr (22 g. Mg)	CdCl ₂ (89 g.)	54.6*	8
C₈H₇OCl				
3-CH ₃ C ₆ H ₄ COCl	CH ₃ MgBr	CdCl ₂	83.0	3
C₈H₇O₂Cl				
4-CH ₃ OC ₆ H ₄ COCl (0.21 mole)	CH ₃ MgBr (0.3 mole)	CdCl ₂ (0.16 mole)	84.0	3
C₈H₁₁OCl				
1-Cyclohexenylacetyl chloride (30 g.)	1-C ₁₀ H ₇ MgBr (90 g. C ₁₀ H ₇ Br)	ZnCl ₂ (85 ml. sat'd Et ₂ O sol'n)	61.3, crude	10
C₈H₁₃O₃Cl				
H ₅ C ₂ O ₂ C(CH ₂) ₄ COCl	CH ₃ MgBr	CdCl ₂	76.0	6,5,9
C₈H₁₅OCl				
CH ₃ (C ₂ H ₅)(<i>n</i> -C ₃ H ₇)CCOCl	CH ₃ MgBr	CdCl ₂	47.0	11

* Recovered in the form of 65 g. of the acid, *i*-C₃H₁₁CO(CH₂)₄CO₂H.

TABLE IX-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Cd or Zn Salt</u>	<u>% Yield Ketone</u>	<u>Ref.</u>
C₉H₇OCl C ₆ H ₅ CH=CHCOCl (0.16 mole)	C ₆ H ₅ MgBr (0.16 mole)	CdCl ₂ (0.16 mole)	44.0	12
C₉H₈OClBr 4-BrC ₆ H ₄ CH ₂ CH ₂ COCl (25 g. acid)	C ₆ H ₅ MgBr (0.45 mole)	ZnCl ₂ (27 g., 0.2 mole)	?	37
C₉H₉OCl (+)-CH ₃ (C ₆ H ₅)CHCOCl (7.3 g. acid)	CH ₃ MgBr (1.5 g. Mg)	CdCl ₂ (4.5 g.)	78.0	13
C₉H₉O₃Cl 2,3-(CH ₃ O) ₂ C ₆ H ₃ COCl 3,5-(CH ₃ O) ₂ C ₆ H ₃ COCl	CH ₃ MgBr CH ₃ MgBr	CdCl ₂ CdCl ₂	71.0 84.0	14 14
C₁₀H₁₁OCl 2,4,6-(CH ₃) ₃ C ₆ H ₂ COCl (10 g.)	2-CH ₃ C ₁₀ H ₆ -1-MgBr (10 g. C ₁₁ H ₉ Br)	CdCl ₂	9.6	15
C₁₀H₁₁O₂Cl C ₆ H ₅ O(CH ₂) ₃ COCl (41.5 g.)	CH ₃ MgBr (7.3 g. Mg)	CdCl ₂ (29.3 g.)	78.0	16
C₁₁H₆OCl₂ 6-ClC ₁₀ H ₆ -1-COCl (0.39 mole)	CH ₃ MgBr	CdCl ₂ [0.30 mole (CH ₃) ₂ Cd]	?	32
C₁₁H₁₀OCl 1,2,3,4-Tetrahydronaphthalene-1-carboxylic acid chloride (0.24 mole)	CH ₃ MgBr (0.48 mole)	CdCl ₂ (48 g.)	65.0	17

TABLE IX-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Cd or Zn Salt</u>	<u>% Yield Ketone</u>	<u>Ref.</u>
C₁₁H₁₃OCl				
2,3,5,6-(CH ₃) ₄ C ₆ HCOC1 (6.0 g.)	4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ MgBr (9.6 g. C ₁₀ H ₁₅ Br)	CdCl ₂ (4.4 g.)	20.0	33
C₁₁H₁₉O₃Cl				
H ₅ C ₂ O ₂ C(CH ₂) ₇ COCl	CH ₃ MgBr	CdCl ₂	64.0	9
H ₅ C ₂ O ₂ C(CH ₂) ₇ COCl (0.72 mole)	CH ₃ (<i>n</i> -C ₈ H ₁₇)CHMgBr (1.27 mole C ₁₀ H ₂₁ Br)	ZnCl ₂ (1.0 mole)	55.0	18
C₁₂H₁₂OCl				
1-(1,2,3,4-Tetrahydronaphthyl)acetyl chloride	CH ₃ MgBr	CdCl ₂	69.0	17
C₁₂H₂₁O₃Cl				
H ₅ C ₂ O ₂ C(CH ₂) ₈ COCl (0.1 mole)	CH ₃ MgBr (0.2 mole Mg)	CdCl ₂ (19.6 g.)	83.7	2,5,6
H ₅ C ₂ O ₂ C(CH ₂) ₈ COCl	<i>i</i> -C ₅ H ₁₁ MgBr	CdCl ₂	85.0	5,6
H ₅ C ₂ O ₂ C(CH ₂) ₈ COCl (26.4 g.)	<i>i</i> -C ₉ H ₁₉ MgBr (22 g. C ₉ H ₁₉ Br)	CdCl ₂	46.0	4
H ₅ C ₂ O ₂ C(CH ₂) ₈ COCl	CH ₃ (C ₂ H ₅)CH(CH ₂) ₅ MgBr	CdCl ₂	76.5	5,6
H ₅ C ₂ O ₂ C(CH ₂) ₈ COCl (8.4 g.)	CH ₃ (<i>n</i> -C ₃ H ₇)CH(CH ₂) ₄ MgBr (10 g. C ₉ H ₁₉ Br)	CdCl ₂	65.0	19
H ₅ C ₂ O ₂ C(CH ₂) ₈ COCl	CH ₃ (<i>n</i> -C ₆ H ₁₃)CH(CH ₂) ₃ MgBr	CdCl ₂	77.0	6
H ₅ C ₂ O ₂ C(CH ₂) ₈ COCl (6.0 g.)	<i>n</i> -C ₁₂ H ₂₅ MgBr (7.5 g. C ₁₂ H ₂₅ Br)	ZnCl ₂ (4.1 g.)	62.0*	20
H ₅ C ₂ O ₂ C(CH ₂) ₈ COCl	<i>n</i> -C ₁₄ H ₂₉ MgBr	ZnCl ₂	?	20
H ₅ C ₂ O ₂ C(CH ₂) ₈ COCl (10.8 g.)	CH ₃ (<i>n</i> -C ₁₀ H ₂₁)CH(CH ₂) ₃ MgBr (15.0 g. C ₁₅ H ₃₁ Br)	CdCl ₂	77.8	19
H ₅ C ₂ O ₂ C(CH ₂) ₈ COCl	<i>n</i> -C ₁₈ H ₃₇ MgBr	ZnCl ₂	77.0	21

* Product isolated as the acid, *n*-C₁₂H₂₅CO(CH₂)₈CO₂H, 62.0% yield.

TABLE IX-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Cd or Zn Salt</u>	<u>% Yield Ketone</u>	<u>Ref.</u>
C₁₃H₁₇OCl				
2,6-(CH ₃) ₂ -4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ COCl	CH ₃ MgBr	CdCl ₂	34.0	22
C₁₃H₂₃O₃Cl				
H ₅ C ₂ O ₂ C(CH ₂) ₉ COCl	<i>n</i> -C ₁₈ H ₃₇ MgBr	ZnCl ₂	92.0	21
CH ₃ CO ₂ (CH ₂) ₁₀ COCl (0.19 mole)	<i>n</i> -C ₁₈ H ₃₇ MgBr (0.24 mole)	ZnCl ₂ (0.30 mole)	88.0	21
C₁₄H₂₅O₃Cl				
H ₅ C ₂ O ₂ C(CH ₂) ₁₀ COCl (0.20 mole)	<i>n</i> -C ₁₈ H ₃₇ MgBr (0.27 mole)	ZnCl ₂ (0.27 mole)	79.0	21
C₁₅H₁₇O₃Cl				
4-(<i>p</i> -Acetoxyphenyl)hexahydrobenzoyl chloride (12.0 g. acid)	C ₂ H ₅ MgBr (0.334 g. Mg)	CdCl ₂ (1.34 g.)	63.0	23
4-(<i>p</i> -Acetoxyphenyl)hexahydrobenzoyl chloride (2.70 g. acid)	<i>n</i> -C ₃ H ₇ MgBr (0.76 g. Mg)	CdCl ₂ (3.04 g.)	75.0	23
C₁₅H₂₇O₃Cl				
H ₅ C ₂ O ₂ C(CH ₂) ₁₁ COCl	<i>n</i> -C ₁₈ H ₃₇ MgBr	ZnCl ₂	89.0	21
C₁₆H₂₉O₃Cl				
H ₅ C ₂ O ₂ C(CH ₂) ₁₂ COCl	<i>n</i> -C ₁₈ H ₃₇ MgBr	ZnCl ₂	76.0	21
C₁₇H₂₃OCl				
RC(CH ₃)=CHCH=CHCOCl* (6.70 g.)	CH ₃ MgBr (0.96 g. Mg)	CdCl ₂ (3.68 g.)	45.0	34
C₁₇H₃₁O₃Cl				
H ₅ C ₂ O ₂ C(CH ₂) ₁₃ COCl	<i>n</i> -C ₁₈ H ₃₇ MgBr	ZnCl ₂	83.0	21

*R = β -(2,6,6-trimethyl-1-cyclohexenyl)vinyl.

TABLE IX-I (Continued)

Halide	RMgX	Cd or Zn Salt	% Yield Ketone	Ref.
C₁₆H₃₃O₃Cl H ₅ C ₂ O ₂ C(CH ₂) ₁₄ COCl	<i>n</i> -C ₁₈ H ₃₇ MgBr	ZnCl ₂	77.0	21
C₁₆H₃₅OCl <i>n</i> -C ₁₇ H ₃₅ COCl (0.06 mole) <i>n</i> -C ₁₇ H ₃₅ COCl (1.41 mole)	C ₂ H ₅ MgBr (0.08 mole C ₂ H ₅ Br) C ₆ H ₅ (CH ₂) ₂ MgBr (1.76 mole C ₈ H ₉ Br)	CdCl ₂ (0.043 mole) CdCl ₂ (0.936 mole)	62.0 65.5	24, 3 24
C₁₉H₃₅O₃Cl H ₅ C ₂ O ₂ C(CH ₂) ₁₅ COCl	<i>n</i> -C ₁₈ H ₃₇ MgBr	ZnCl ₂	80.0	21
C₂₄H₃₅O₂Cl 3-Oxo-4-etiocholenic acid chloride (595 mg. Na salt)	C ¹⁴ H ₅ MgBr (6 ml. CH ₃ OH + 0.599 mmole C ¹⁴ H ₅ OH)	CdCl ₂ (1.4 mmole)	29.2*	26
C₂₄H₃₅O₃Cl 3-Acetoxy-5-bisnorcholenic acid chloride (4.0 g.) 3-Acetoxy-5-bisnorcholenic acid chloride 3-Acetoxy-5-bisnorcholenic acid chloride (25 g. acid) 3-Acetoxy-5-bisnorcholenic acid chloride (18 g.) 3-Acetoxy-5-bisnorcholenic acid chloride 3-Acetoxy-5-bisnorcholenic acid chloride (6 g.)	CH ₃ MgX (X = Br, I) (1.3 g. Mg) C ₂ H ₅ MgBr <i>i</i> -C ₅ H ₁₁ MgBr (8 g. Mg) C ₆ H ₅ MgBr (32 g. C ₆ H ₅ Br) C ₆ H ₅ MgBr 2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (3 g. Mg)	CdCl ₂ (5.0 g.) CdCl ₂ CdCl ₂ (38 g.) CdCl ₂ (28 g.) ZnCl ₂ CdCl ₂ (11 g.)	95.0 93.5 91.2 97.9 88.4 45.8	25 25 25 25 25 25
C₂₄H₃₅O₃Cl 3,12-Diformoxybisnorcholanic acid chloride (0.02 mole acid)	C ₆ H ₅ MgBr (1.95 g. Mg)	CdCl ₂ (8.8 g.)	81.0	27

* Based on C¹⁴H₅OH used for preparation of C¹⁴H₅Br.

TABLE IX-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Cd or Zn Salt</u>	<u>% Yield Ketone</u>	<u>Ref.</u>
C₂₄H₃₉OCl Cholanic acid chloride	C ₆ H ₅ MgBr	CdCl ₂	?	27
C₂₄H₃₉O₃Cl 3-Formoxynorcholanic acid chloride	C ₆ H ₅ MgBr	CdCl ₂	?	27
C₂₄H₃₉O₄Cl Cholic acid chloride	C ₆ H ₅ MgBr	CdCl ₂	70-75	28
C₂₅H₃₇O₃Cl 3(β)-Formoxy-5-cholenic acid chloride	C ₆ H ₅ MgBr	CdCl ₂	?	27
C₂₅H₃₇O₄Cl 3-Formoxy-12-oxocholanic acid chloride	C ₆ H ₅ MgBr	CdCl ₂	?	27
C₂₅H₃₉O₃Cl 3-Formoxycholanic acid chloride	C ₆ H ₅ MgBr	CdCl ₂	?	27
C₂₆H₃₉O₃Cl 3-Acetoxy-5-cholenic acid chloride (25.0 g. acid)	<i>i</i> -C ₃ H ₇ MgBr (14.65 g. Mg)	CdBr ₂ (88.0 g.)	?	29
3-Acetoxy-5-etiocholenic acid chloride (1.82 g. acid)	C ¹⁴ H ₃ MgI (726 mg. C ¹⁴ H ₃ I)	CdBr ₂ (1.2 g.)	50.6, * crude	30
3(β)-Acetoxy-5-etiocholenic acid chloride	CH ₃ MgBr	CdCl ₂	31.0	26
3(β)-Acetoxy-5-etiocholenic acid chloride	<i>i</i> -C ₅ H ₁₁ MgBr	CdCl ₂	?	31
C₂₆H₄₁O₃Cl 3(β)-Acetoxyetioallocholanic acid chloride	<i>i</i> -C ₅ H ₁₁ MgBr	CdCl ₂	?	31

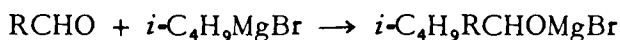
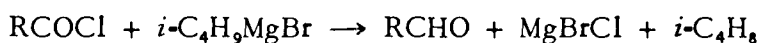
* Based on C¹⁴H₃I used.

REFERENCES FOR TABLE IX-I

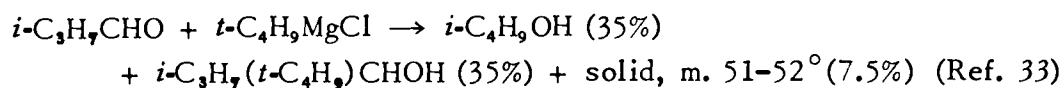
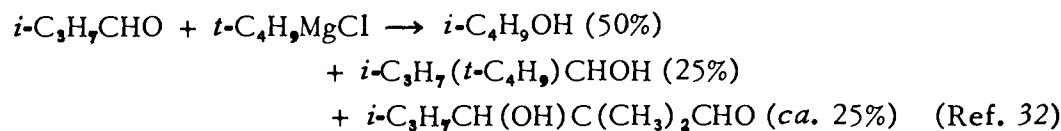
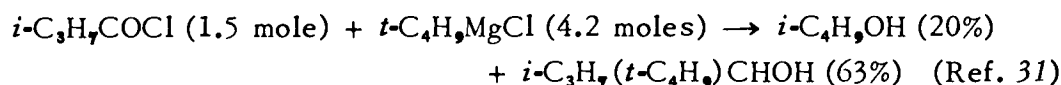
- (1) Bunnett and Tarbell, *J. Am. Chem. Soc.*, 67, 1944-6 (1945).
- (2) Cason, *J. Am. Chem. Soc.*, 68, 2078-81 (1946).
- (3) Gilman and Nelson, *Rec. trav. chim.*, 55, 518-30 (1936).
- (4) Cason, *J. Am. Chem. Soc.*, 64, 1106-10 (1942).
- (5) Cason and Prout, *J. Am. Chem. Soc.*, 66, 46-50 (1944).
- (6) Cason and Prout, *Organic Syntheses*, 28, 75-80 (1948).
- (7) Bachman and Micucci, *J. Am. Chem. Soc.*, 70, 2381-4 (1948).
- (8) Wilson, *J. Am. Chem. Soc.*, 67, 2161-2 (1945).
- (9) McKennis and du Vigneaud, *J. Am. Chem. Soc.*, 68, 832-5 (1946).
- (10) Kon and Woolman, *J. Chem. Soc.*, 1939, 794-800.
- (11) Lester and Proffitt, *J. Am. Chem. Soc.*, 71, 1877-8 (1949).
- (12) Nightingale and Wadsworth, *J. Am. Chem. Soc.*, 67, 416-8 (1945).
- (13) Campbell and Kenyon, *J. Chem. Soc.*, 1946, 25-7.
- (14) Woodruff, *J. Am. Chem. Soc.*, 64, 2859-62 (1942).
- (15) Fuson, McKusick, and Spangler, *J. Am. Chem. Soc.*, 67, 597-601 (1945).
- (16) Brown and Partridge, *J. Am. Chem. Soc.*, 67, 1423-4 (1945).
- (17) Newman and O'Leary, *J. Am. Chem. Soc.*, 68, 258-61 (1946).
- (18) Schmidt and Shirley, *J. Am. Chem. Soc.*, 71, 3804-6 (1949).
- (19) Cason, Adams, Bennett, and Register, *J. Am. Chem. Soc.*, 66, 1764-7 (1944).
- (20) Schneider and Spielman, *J. Biol. Chem.*, 142, 345-54 (1942).
- (21) Jones, *J. Am. Chem. Soc.*, 69, 2350-4 (1947).
- (22) Fuson, Mills, Klose, and Carpenter, *J. Org. Chem.*, 12, 587-95 (1947).
- (23) Johnson and Offenhauer, *J. Am. Chem. Soc.*, 67, 1045-9 (1945).
- (24) Sherk, Augur, and Soffer, *J. Am. Chem. Soc.*, 67, 2239-40 (1945).
- (25) Cole and Julian, *J. Am. Chem. Soc.*, 67, 1369-75 (1945).
- (26) Riegel and Prout, *J. Org. Chem.*, 13, 933-6 (1948).
- (27) Hoehn and Moffett, *J. Am. Chem. Soc.*, 67, 740-3 (1945).
- (28) Jacobsen, *J. Am. Chem. Soc.*, 66, 662 (1944).
- (29) Riegel and Kaye, *J. Am. Chem. Soc.*, 67, 723-4 (1945).
- (30) MacPhillamy and Scholz, *J. Biol. Chem.*, 178, 37-40 (1949).
- (31) Billeter and Miescher, *Helv. Chim. Acta*, 32, 564-73 (1949).
- (32) Jacobs, Winstein, Henderson, Bond, Ralls, Seymour, and Florsheim, *J. Org. Chem.*, 11, 229-38 (1946).
- (33) Fuson and McKusick, *J. Am. Chem. Soc.*, 65, 60-4 (1943).
- (34) Heilbron, Jones, and O'Sullivan, *J. Chem. Soc.*, 1946, 866-9.
- (35) Dauben, *J. Am. Chem. Soc.*, 70, 1376-8 (1948).
- (36) Gaertner, *J. Am. Chem. Soc.*, 73, 3934-7 (1951).
- (37) Johnson, Jacobs, and Schwartz, *J. Am. Chem. Soc.*, 60, 1885-9 (1938).
- (38) Frank and Weatherbee, *J. Am. Chem. Soc.*, 70, 3482-3 (1948).

REDUCTION OF ACID HALIDES BY GRIGNARD REAGENTS

Unlike the corresponding carboxylic esters (*q.v.*, Chapter VIII) some carbonyl chlorides are reduced, in part, by Grignard reagents to the corresponding primary alcohols. Such reductions are always accompanied by the production of a secondary alcohol identical with the reduction product of the ketone which might be expected as the product of the first stage of reaction of the Grignard reagent with the carbonyl chloride. Reductions of this kind are effected by Grignard reagents of the same type responsible for the reduction of aldehydes and ketones (*q.v.*, Chapter VI), and olefin is formed in amount corresponding to two equivalents of Grignard reagent for each equivalent of acid chloride reduced to primary alcohol plus one equivalent of Grignard reagent for each equivalent of secondary alcohol produced.²⁹ These facts suggest that the primary and secondary alcohols may have, as Whitmore *et al.*³⁰ maintain, in part at least, a common origin. For example, isobutylmagnesium bromide, an efficient reducing agent, may react with a readily reducible acid chloride in in part as follows.



A test of the consistency of this hypothesis with known facts (though not, of course, a conclusive proof of its validity) is to be found in a comparison of the reactions of isobutyryl chloride with *t*-butylmagnesium chloride, reported by Whitmore,³¹ on the one hand, and of isobutyraldehyde with the same Grignard reagent, reported by Faworsky³² and by Whitmore and Houk,³³ on the other.



A further comparison may be made between the reactions of *t*-butylmagnesium chloride with trimethylacetyl chloride, reported by Whitmore

²⁹ Greenwood, Whitmore, and Crooks, *J. Am. Chem. Soc.*, 60, 2028–30 (1938).

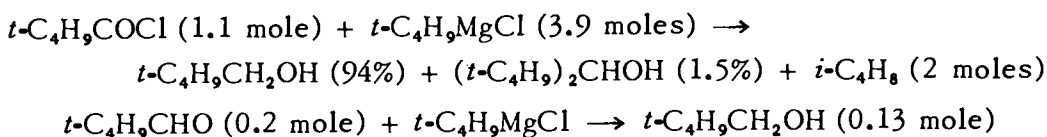
³⁰ Whitmore, Whitaker, Mosher, Breivik, Wheeler, Miner, Sutherland, Wagner, Clapper, Lewis, Lux, and Popkin, *J. Am. Chem. Soc.*, 63, 643–54 (1941).

³¹ Whitmore, *Rec. trav. chim.*, 57, 562–8 (1938).

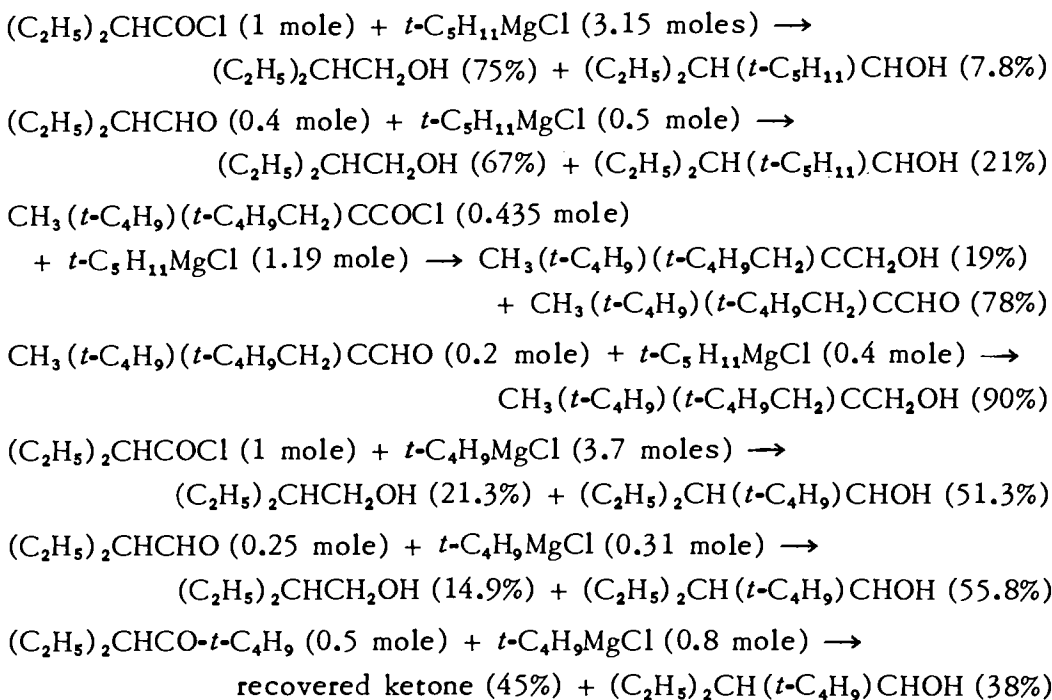
³² Faworsky, *J. prakt. Chem.*, [2], 88, 641–98 (1913).

³³ Whitmore and Houk, *J. Am. Chem. Soc.*, 54, 3714–8 (1932).

(*loc. cit.*³¹), on the one hand, and trimethylacetaldehyde, reported by Conant *et al.*,³⁴ on the other.



Whitmore *et al.* (*loc. cit.*³⁰) have made additional comparisons of the reactions of related acyl chlorides and aldehydes with *t*-amylmagnesium chloride, and of a related acyl chloride, aldehyde, and ketone with *t*-butylmagnesium chloride.

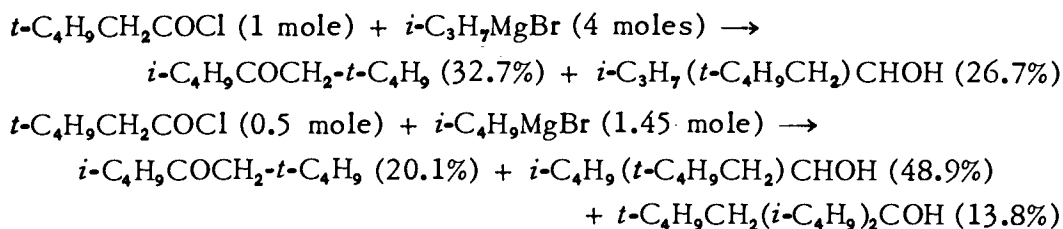


The isolation of traces (*ca.* 1 percent) of aldehydes from the trimethylacetyl and *t*-butylacetyl chloride reactions with *t*-butylmagnesium chloride, and of relatively high yields (67.0 percent, 62.5 percent) of aldehyde from the reactions of methyl-*t*-butylneopentylacetyl chloride with *t*-butyl- and *t*-amylmagnesium chlorides, by Whitmore *et al.* (*loc. cit.*³⁰) is also in accord with the reaction scheme proposed.

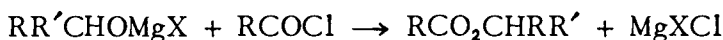
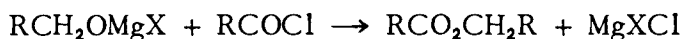
There remains, of course, the possibility (in some cases the strong probability) that secondary alcohol is formed, at least in part, by the reduction of intermediate ketone in the manner already discussed (see Grignard Reductions of Aldehydes and Ketones, Chapter VI). This mode of secondary alcohol formation seems especially probable in such reactions as those of *t*-butylacetyl chloride with isopropyl- and isobutylmagnesium bromides, reported by Whitmore and Forster.³⁵

³⁴Conant, Webb, and Mendum, *J. Am. Chem. Soc.*, 51, 1246-55 (1929).

³⁵Whitmore and Forster, *J. Am. Chem. Soc.*, 64, 2966-8 (1942).



When reactions in which reduction occurs are conducted under conditions involving the presence (even temporary) of an excess of acid chloride, the reduction products are, of course, recovered in whole or in part as esters.



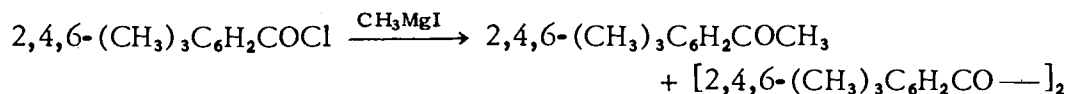
ESTER FORMATION THROUGH ETHER CLEAVAGE

Whitmore and Wheeler³⁶ have reported ethyl acetate as a byproduct of the reactions of acetyl chloride with several Grignard reagents in etheral solution. It is well known that acid chlorides (and anhydrides) cleave ethers in the presence of suitable metallic halide catalysts, notably zinc chloride.³⁷ It has been shown by Whitmore and Wheeler (*loc. cit.*³⁶) that acetyl chloride cleaves ethyl ether in the presence of anhydrous magnesium chloride.

A different type of ether cleavage has been observed by Jacobs *et al.*,³⁸ who report that both benzoyl bromide and benzoyl chloride react with phenoxyethynylmagnesium bromide to give phenyl benzoate (principally) and phenol as the only identifiable products.

COUPLING

A "coupling" reaction formally similar to those which have been observed with some aralkyl halides, (*q.v.*, Chapter XVI) has been reported by Fuson and Corse.³⁹ Mesitoyl chloride reacts with methylmagnesium iodide to yield both acetomesitylene and bimesitoyl (2,2',4,4',6,6'-hexamethylbenzil).



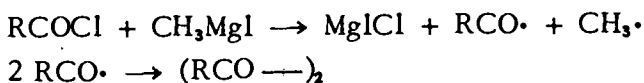
Such reactions would appear to be most credibly explicable as consequences of the ability of some organomagnesium halides (especially iodides) to undergo homolytic as well as ionic scission.

³⁶Whitmore and Wheeler, *J. Am. Chem. Soc.*, 60, 2899-900 (1938).

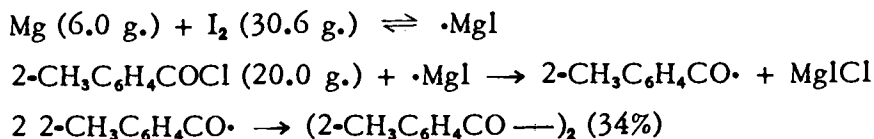
³⁷See, *e.g.*: Meerwein and Maier-Huser, *J. prakt. Chem.*, [2], 134, 51-81 (1932).

³⁸Jacobs, Cramer, and Weiss, *J. Am. Chem. Soc.*, 62, 1849-54 (1940).

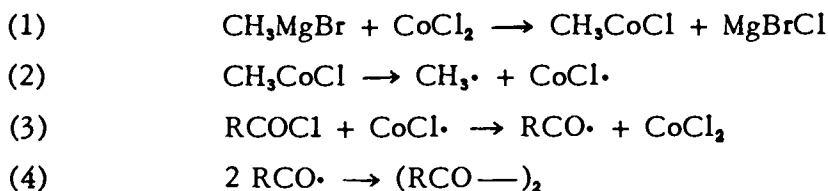
³⁹Fuson and Corse, *J. Am. Chem. Soc.*, 60, 2063-6 (1938).



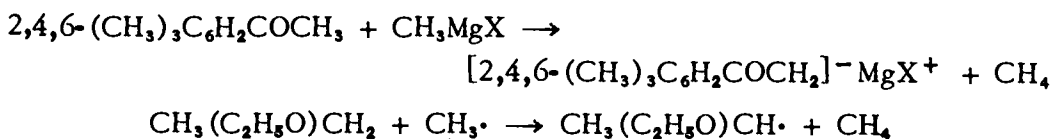
Support for this view is to be found in the magnesian iodide reduction of *o*-toluyl chloride, reported by Fuson and Rachlin.^{39,41} The equation relating the simple stoichiometric facts may be expanded to incorporate the theoretical interpretation as follows:



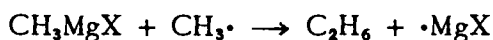
This type of reaction has been further studied by Kharasch *et al.*,⁴⁰ who found that, whereas methylmagnesium bromide reacts with mesitoyl chloride to yield 87 percent acetomesitylene with negligible quantities (*ca.* 1 percent) of the benzil derivative, the addition of "catalytic" quantities of cobaltous chloride to the reaction mixture under the same conditions reduces the yield of ketone to 35 percent and increases the yield of benzil derivative to 31 percent. The suggested reaction scheme is:



The gaseous byproduct was reported, though apparently not experimentally identified, by Fuson and Corse (*loc. cit.*³⁹) as ethane. Kharasch *et al.* (*loc. cit.*⁴⁰) found the gaseous product to consist of methane, ethane, and ethylene, with ethane present in greater quantity than ethylene. The methane is attributed in part to the enolization of acetomesitylene and in part to attack of methyl radicals on ether.



Ethane and ethylene would presumably be produced in equimolecular proportions by decomposition of the free radicals produced by the attack of methyl radicals on ether. The excess of ethane may be due to the attack of methyl radicals on the Grignard reagent.



In a similar experiment employing mesitoyl chloride, phenylmagnesium bromide, and cobaltous chloride, Kharasch *et al.* (*loc. cit.*⁴⁰) obtained a 21 percent yield of a product attributable to reductive dimerization of the

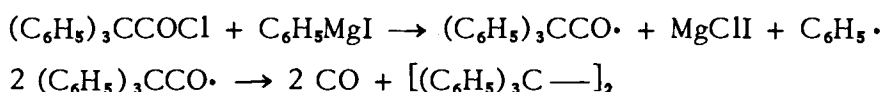
^{39,41} Fuson and Rachlin, *J. Am. Chem. Soc.*, 68, 343 (1946).

⁴⁰ Kharasch, Morrison, and Urry, *J. Am. Chem. Soc.*, 66, 368-71 (1944).

ketone formed in the first stage of the "normal" carbonyl halide-Grignard reagent reaction.*

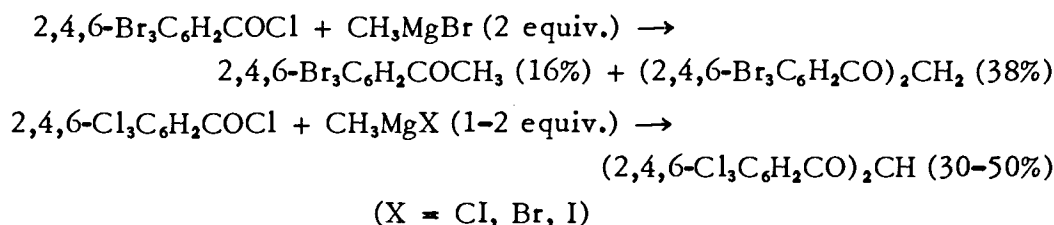
HEXAARYLETHANE FORMATION

Schmidlin⁴¹ found that, although phenylmagnesium bromide reacts "normally" with triphenylacetyl chloride to give the tertiary alcohol in 41 percent yield, phenylmagnesium iodide, under similar conditions, yields only a trace of the alcohol, with hexaphenylethane (or triphenylmethyl peroxide) as the isolable solid product, together with carbon monoxide corresponding to 86 percent of the acid chloride used. Probably this reaction is similar to that which leads to benzil formation, differing from it only by reason of the relative stabilities of the intermediate acyl free radicals formed.



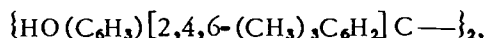
KETONE ENOLIZATION AND C-ACYLATION

The production of dibenzoylmethane derivatives in yields as high as 50 percent has been effected by Fuson *et al.*⁴² through the interaction of methylmagnesium halides with 2,4,6-tribromo- and 2,4,6-trichlorobenzoyl chlorides.

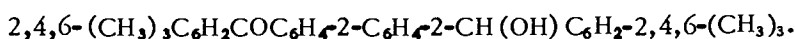


In view of the behavior of acetomesitylene, which reacts quantitatively with methyl Grignard reagents to form an enolate that undergoes C-acylation, and otherwise behaves like a true Grignard reagent of the formula 2,4,6-(CH₃)₃C₆H₂COCH₂MgX, these reactions are readily interpretable as follows:

*This product, originally reported as the pinacol,



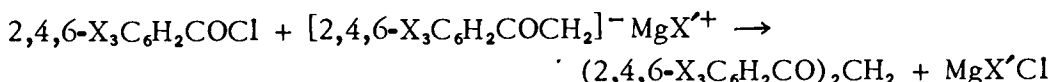
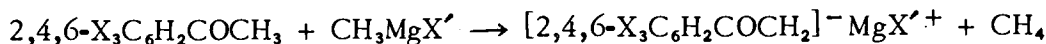
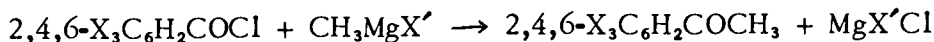
has since been shown by Fuson and Hornberger, *J. Org. Chem.*, 16, 631-6 (1951), to be mesityl 2'-(mesitylhydroxymethyl)-2-biphenyl ketone,



For a discussion of its probable mode of formation, see Magnesium Halide Reduction, Chapter VI.

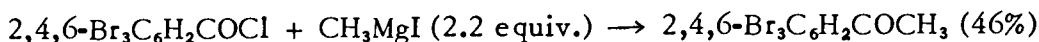
⁴¹Schmidlin, *Ber.*, 43, 1137-44 (1910).

⁴²(a) Ross and Fuson, *J. Am. Chem. Soc.*, 59, 1508-10 (1937); (b) Fuson, Van Campen, and Wolf, *ibid.*, 60, 2269-72 (1938).

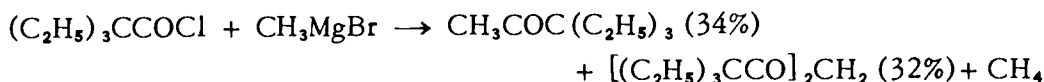


Fuson found, in fact, that the iodomagnesium enolate of the trichloroacetophenone reacts with the trichlorobenzoyl chloride to give the dibenzoylmethane.

When, however, the chloride is added slowly to an excess of Grignard reagent the monoketone is obtained without diketone formation.

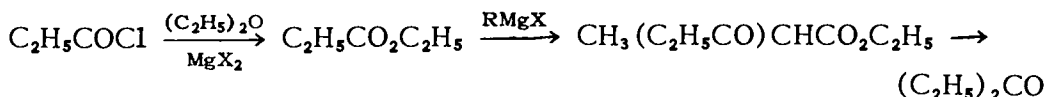


Another instance of enolate C-acylation has been reported by Whitmore and Lewis.⁴³

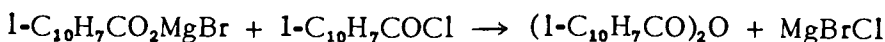


OTHER "ABNORMAL" REACTIONS

Petrov and Roslova⁴⁴ have reported 3-pentanone as among the products of the reaction of propionyl chloride with *t*-butylmagnesium chloride. The available abstract contains no details regarding the conditions of reaction save that three hours warming on the water-bath was involved. If this product has been correctly characterized, it is probably attributable to the same cause as the analagous ketone formation in ester reactions (*q.v.*, Chapter VIII). Ester formed through ether cleavage might undergo Claisen condensation; decarbethoxylation of the keto ester thus derived would yield the ketone reported.



The formation of 1-naphthoic anhydride during the reaction of 1-naphthoyl chloride with 7-isopropyl-4-indanylmagnesium bromide has been observed by Bruce.⁴⁵ The mode of formation of the anhydride has not been demonstrated, but, if acid salt were formed under the reaction conditions (say, from contaminant free acid), the anhydride would be among the expected products.



Whitmore and Wheeler⁴⁶ have discovered mesityl oxide and isobutane among the products of reaction of acetyl chloride with *t*-butylmagnesium

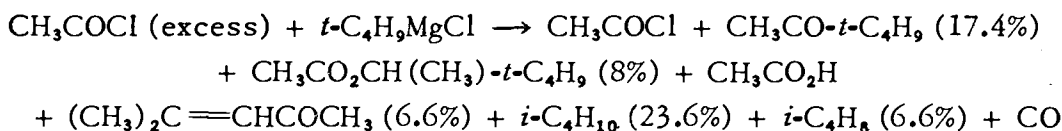
⁴³Whitmore and Lewis, *J. Am. Chem. Soc.*, 64, 1618-9 (1942).

⁴⁴Petrov and Roslova, *J. Gen. Chem.*, (U.S.S.R.), 10, 973-6 (1940); *Chem. Abstr.*, 35, 2467 (1941).

⁴⁵Bruce, *J. Am. Chem. Soc.*, 60, 2277 (1938); Bruce and Todd, *ibid.*, 61, 157-61 (1939).

⁴⁶Whitmore and Wheeler, *J. Am. Chem. Soc.*, 60, 2899-900 (1938).

chloride. Whitmore points out that Karasev⁴⁷ has reported acetone and acetone condensates as products of the reaction of ethyl acetate with *t*-butylmagnesium chloride, and suggests that some of the ethyl acetate formed by acetyl chloride cleavage of ether may be converted to mesityl oxide. Alternatively, he suggests that isobutylene may condense with acetyl chloride in the presence of magnesium chloride. The isobutane is attributed to the enolization of mesityl oxide and pinacolin.

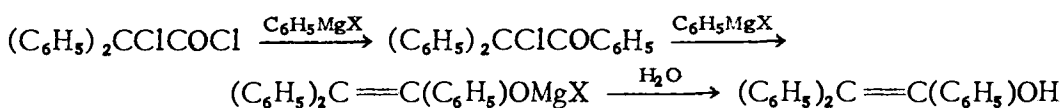


The formation of *o*-tolyl derivatives in the reactions of benzylmagnesium chloride with acetyl chloride and with chloroformic esters have been reported by Whitmore and Sloat⁴⁸ and by Austin and Johnson,⁴⁹ respectively. Whereas such reactions are illustrative of an idiosyncrasy of the benzyl Grignard reagents, and are affected only secondarily by the co-reactant, they are discussed under the topic, Allylic Rearrangements in Grignard Reactions (*q.v.*, Chapter XVII).

α-HALO CARBONYL HALIDES

The few reported reactions of Grignard reagents with α-halo carbonyl chlorides are those which one would be led to expect by the corresponding reactions of α-halo ketones (*q.v.*, Chapter VI).

For example, McKenzie and Boyle⁵⁰ record that the reaction of phenylmagnesium bromide (or iodide) with α-chlorodiphenylacetyl chloride, and subsequent hydrolysis of the Grignard complex, leads to triphenylvinyl alcohol.



The reactions of bromoacetyl bromide and chloroacetyl chloride with methylmagnesium halides, reported by Huston *et al.*,⁵¹ and that of chloroacetyl chloride with phenylmagnesium bromide, reported by Boyle *et al.*,⁵² yield products identical with, or analogous to, that obtained by Henry⁵³ in the reaction of chloroacetone with methylmagnesium bromide, and are adequately accounted for by extension of the reaction series proposed by Henry.

⁴⁷Karasev, *J. Gen. Chem. (U.S.S.R.)*, 7, 179–84 (1937); *Chem. Abstr.*, 31, 4268 (1937).

⁴⁸Whitmore and Sloat, *J. Am. Chem. Soc.*, 64, 2968–70 (1942).

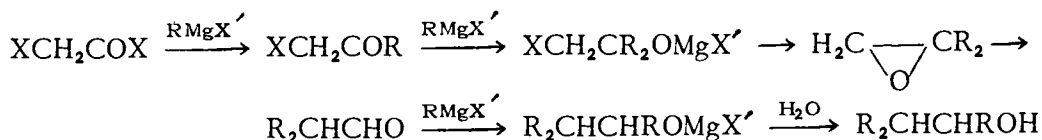
⁴⁹Austin and Johnson, *J. Am. Chem. Soc.*, 54, 647–60 (1932).

⁵⁰McKenzie and Boyle, *J. Chem. Soc.*, 119, 1131–40 (1921).

⁵¹Huston, Jackson, and Spero, *J. Am. Chem. Soc.*, 63, 1459–60 (1941).

⁵²Boyle, McKenzie, and Mitchell, *Ber.*, 70B, 2153–60 (1937).

⁵³Henry, *Compt. rend.*, 145, 21–25 (1907); *Chem. Zentr.*, 1907, II, 889; *Chem. Abstr.*, 1, 2682 (1907).

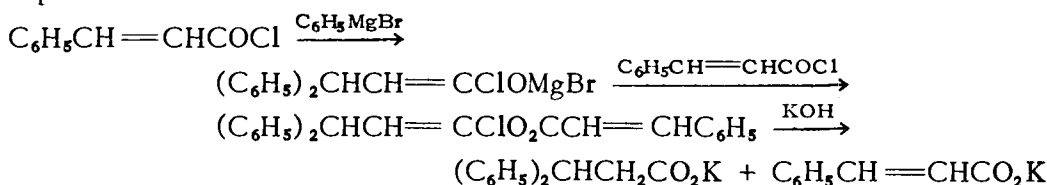


α,β -UNSATURATED CARBONYL HALIDES

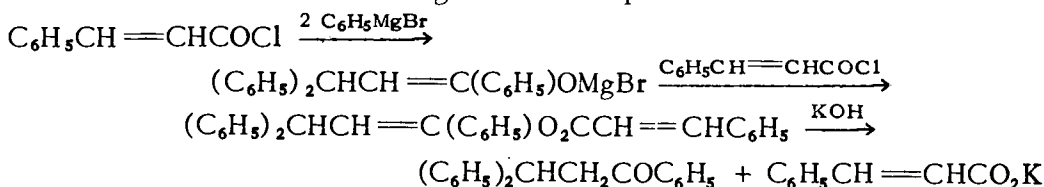
The α,β -unsaturated carbonyl halides have been but little investigated. Their reactions with Grignard reagents, however, appear to resemble those of the corresponding α,β -unsaturated esters (*q.v.*, Chapter VIII), and to be foreshadowed in part by the reactions of the α,β -unsaturated ketones (*q.v.*, Chapter VI) which may be postulated as possible intermediates.

Kohler and Heritage⁵⁴ brought about the reaction of cinnamoyl chloride with phenylmagnesium bromide in dilute ethereal solution at -20° under conditions not specified in detail. The viscous liquid product "obtained in the usual way," was first extracted by steam-distillation to remove traces of bromobenzene and biphenyl, and was then extracted with hot water, which removed a small amount of cinnamic acid. The residue was then submitted to alkaline hydrolysis. The alkali-insoluble fraction proved to be chiefly α,β -diphenylpropiophenone. Acidification of the alkaline filtrate precipitated cinnamic and α,β -diphenylpropionic acids, which were separated by fractional crystallization.

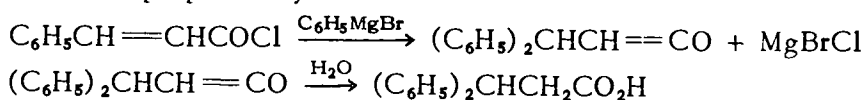
Kohler accounted for the production of α,β -diphenylpropionic acid and a part of the cinnamic acid as follows:



α,β -Diphenylpropiophenone and the remainder of the cinnamic acid were attributed to the following reaction sequence:



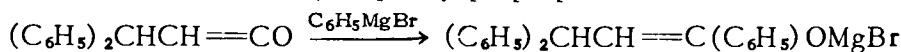
An explanation of α,β -diphenylpropionic acid production at least as credible as that proposed by Kohler would be:



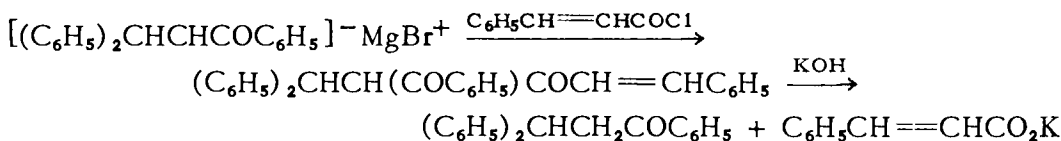
Being non-volatile with steam and virtually water-insoluble, the propionic acid would appear in the alkaline hydrolysate.

⁵⁴Kohler and Heritage, *Am. Chem. J.*, 33, 21-35 (1905).

In the presence of excess Grignard reagent the ketene would be converted to the enolate of α,β -diphenylpropionophenone.

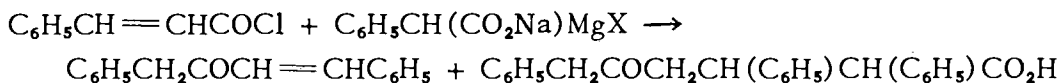


Incidentally, on the basis of the experimental evidence presented, this enolate (structurally identical with that produced by the 1,4-addition of phenylmagnesium bromide to benzalacetophenone) need not necessarily undergo *O*-acylation upon further reaction with acid chloride. *C*-Acylation would yield a ketone of a type readily cloven by alkali to form the same products that would be expected to result from hydrolysis of the ester.⁵⁵



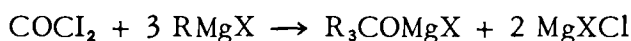
This carbonyl chloride-Grignard reagent reaction, and others like it would repay further study.

Ivanoff and Nicoloff⁵⁶ have studied the reaction of cinnamoyl chloride with the "Grignard reagent" derived from sodium phenylacetate. Ketone formation (and decarboxylation), together with some 1,4-addition to the unsaturated ketone, are reported.

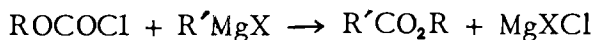


CARBONYL HALIDES OTHER THAN THOSE OF THE TYPE RCOX

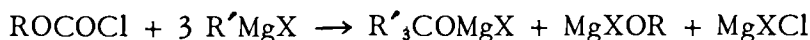
Phosgene has been used by Grignard⁵⁷ and others (see Table IX-II) to prepare tertiary alcohols in which all three carbinol substituents are supplied by the Grignard reagent.



The chloroformic esters are at once esters and acyl chlorides. Whereas the carbonyl chlorine is the more reactive of the two functional groups, esters may be prepared by the addition of one equivalent of Grignard reagent to a chloroformic ester solution.



When an excess of Grignard reagent is used a tertiary alcohol is formed.



For this reason chloroformic ester reactions are included in both the ester (Table VIII-III) and carbonyl halide (Table IX-II) tabulations.

⁵⁵See: Kohler and Peterson, *J. Am. Chem. Soc.*, 55, 1073-82 (1933).

⁵⁶Ivanoff and Nicoloff, *Bull. soc. chim.*, [4], 51, 1331-7 (1932).

⁵⁷It has been suggested by Schlenk, Hillemann, and Rodloff, *Ann.*, 487, 135-54 (1931), that this compound should be formulated as an enolate.

⁵⁸Grignard, *Compt. rend.*, 136, 815-7 (1903); *Chem. Zentr.*, 1903, I, 1077.

TABLE IX-II
REACTIONS OF GRIGNARD REAGENTS WITH CARBONYL HALIDES

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
COCl ₂			
COCl ₂	<i>n</i> -C ₃ H ₇ MgBr (3 equiv.)	<i>n</i> -(C ₃ H ₇) ₂ CHOH; (<i>n</i> -C ₃ H ₇) ₃ COH	1
COCl ₂	Pyrryl-MgBr	2-Pyrryl ketone (28.5%)	130, 94, 95
COCl ₂ (25 ml. 20% sol'n)	2-Methylpyrryl-MgBr (8 g. C ₃ H ₇ N)	Bis(5-methyl-2-pyrryl) ketone (5-6 g.)	94
COCl ₂	<i>i</i> -C ₅ H ₁₁ MgBr (2 equiv.)	(<i>i</i> -C ₅ H ₁₁) ₂ C=CH- <i>i</i> -C ₄ H ₉	1
COCl ₂	<i>i</i> -C ₅ H ₁₁ MgBr (3 equiv.)	(<i>i</i> -C ₅ H ₁₁) ₂ CHOH; (<i>i</i> -C ₅ H ₁₁) ₃ COH	1
COCl ₂	C ₆ H ₅ MgBr (3 equiv.)	(C ₆ H ₅) ₃ COH (50%)	2
COCl ₂ (15 ml. 20% sol'n)	2-Ethylpyrryl-MgBr (5.7 g. C ₆ H ₉ N)	Bis(5-ethyl-2-pyrryl) ketone (ca. 60%)	94
COCl ₂ (25 ml. 20% sol'n)	2,3-Dimethylpyrryl-MgBr (9.5 g. C ₆ H ₉ N)	Bis(4,5-dimethyl-2-pyrryl) ketone	94
COCl ₂	C ₆ H ₅ CH ₂ MgBr (2 equiv.)	(C ₆ H ₅ CH ₂) ₃ COH (35-40%)	2
COCl ₂	4-CH ₃ C ₆ H ₄ MgBr (3 equiv.)	(4-CH ₃ C ₆ H ₄) ₃ COH ("moderate yield")	2
COCl ₂	2-Methyl-4-ethylpyrryl-MgBr	Bis(3-ethyl-5-methyl-2-pyrryl) ketone (30-35%)	94
COCl ₂ (25 ml. 20% sol'n)	Xanthopyrryl-MgBr (10 g. C ₇ H ₁₁ N)	Bis(3-methyl-5-ethyl-2-pyrryl) ketone (7.0-7.5 g.)	94
COCl ₂	2,3,4-Trimethylpyrryl-MgBr (12 g. C ₇ H ₁₁ N)	Bis(3,4,5-trimethyl-2-pyrryl) ketone (10-11 g.)	94
COCl ₂ (1.22 g.)	Indolyl-MgBr (2.50 g. C ₈ H ₇ N)	3-Indolyl ketone	96
COCl ₂	C ₆ H ₅ CH(CO ₂ Na)MgCl* (2 equiv.)	(C ₆ H ₅ CH ₂ CO) ₂ O (78.1%); C ₆ H ₅ CH ₂ CO ₂ H (15.6%); CO ₂ ; CO	97
COCl ₂	2-Methyl-3-carbethoxypyrryl-MgBr (1.5 g. C ₈ H ₁₁ NO ₂)	Bis(4-carbethoxy-5-methyl-2-pyrryl) ketone (15-20%)	94
COCl ₂	2,4-Diethylpyrryl-MgBr (10 g. C ₈ H ₁₃ N)	Bis(3,5-diethyl-2-pyrryl) ketone (4-6 g.)	94

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE IX-II (Continued)

Halide	RMgX	Product(s)	Ref.
COCl₂ (cont.)			
COCl ₂	2-Methylindolyl-MgBr	Bis (α-methyl-β-indolyl) ketone	96
COCl ₂ (15 ml. 20% sol'n)	2-Methyl-3,4-diethylpyrryl-MgBr	Bis (3,4-diethyl-5-methyl-2-pyrryl) ketone	94
COCl ₂	2,4-Dimethyl-3- <i>n</i> -propylpyrryl-MgBr	Bis(3,5-dimethyl-4- <i>n</i> -propyl-2-pyrryl) ketone	94
COCl ₂	2,3-Diethyl-4-methylpyrryl-MgBr (4.2 g. C ₉ H ₁₅ N)	Bis (3-methyl-4,5-diethyl-2-pyrryl) ketone (2.5 g.)	94
COCl ₂	2,3,4-Triethylpyrryl-MgBr (1.6 g. C ₁₀ H ₁₇ N)	Bis(3,4-5-triethyl-2-pyrryl) ketone (20-25%)	94
COCl ₂ (25 ml. 20% sol'n)	2,3-Diethyl-4- <i>n</i> -propylpyrryl-MgBr (13 g. C ₁₁ H ₁₉ N)	Bis(3- <i>n</i> -propyl-4,5-diethyl-2-pyrryl) ketone	94
COCl ₂ (5 ml.)	2,4,6-(C ₆ H ₅) ₃ C ₆ H ₂ MgBr (50 g. C ₂₄ H ₁₇ Br)	[2,4,6-(C ₆ H ₅) ₃ C ₆ H ₂ —] ₂ (8 g.); [2,4,6-(C ₆ H ₅) ₃ C ₆ H ₂] ₂ CO (6 g.); 2,4,6-(C ₆ H ₅) ₃ C ₆ H ₃	3
C₂OCl₄			
Cl ₃ CCOCl	C ₂ H ₅ MgBr	Cl ₃ C(C ₂ H ₅)CHOH	98
C₂O₂Cl₂			
(—COCl) ₂	Cryptopyrryl-MgBr (10.0 g. C ₈ H ₁₃ N)	1,2-Bis (3,5-dimethyl-4-ethyl-2-pyrryl)-1,2-ethanedione	99
(—COCl) ₂ (0.6 g.)	C ₆ H ₅ C≡CMgBr (3.1 g. C ₈ H ₆)	C ₃₄ H ₂₂ O ₂ (0.1 g.)	103
C₂H₂OCl₂			
ClCH ₂ COCl	CH ₃ MgBr (3 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH	5
ClCH ₂ COCl	CH ₃ MgBr (4 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (51%)	4
ClCH ₂ COCl	CH ₃ MgI (4 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (48%)	4
ClCH ₂ COCl	Pyrryl-MgBr	2-Chloroacetylpyrrole	100

TABLE IX-II (Continued)

<u>Halide.</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₂OCl₂ (cont.)			
ClCH ₂ COCl (28 g.)	C ₆ H ₅ MgBr (230 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ CHCH(OH)C ₆ H ₅ (36 g.); ClCH ₂ C(C ₆ H ₅) ₂ OH (0.3 g.)	6
ClCH ₂ COCl	Indolyl-MgBr	3-Chloroacetylindole; 2-chloroacetylindole (?)	7
ClCH ₂ COCl (5.6 g.)	3-Methylindolyl-MgBr (6.5 g. C ₉ H ₉ N)	2-Chloroacetyl-3-methylindole	7
C₂H₂OBr₂			
BrCH ₂ COBr	CH ₃ MgBr (4 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (21%)	4
BrCH ₂ COBr	CH ₃ MgI (4 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (16%)	4
C₂H₃OCl			
CH ₃ COCl	CH ₃ MgI	(CH ₃) ₃ COH	8
CH ₃ COCl	Pyrryl-MgI (1 equiv.)	2-Acetylpyrrole (50-60%)	9
CH ₃ COCl (2 moles)	<i>n</i> -C ₄ H ₉ MgBr (5 moles C ₄ H ₉ Br)	CH ₃ (<i>n</i> -C ₄ H ₉) ₂ COH; CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (13%); <i>n</i> -C ₄ H ₉ OH; C ₂ H ₅ OH (8%)	10, 11
CH ₃ COCl (236 g.)	<i>t</i> -C ₄ H ₉ MgCl (2.26 moles)	CH ₃ CO- <i>t</i> -C ₄ H ₉ ((40.7%))	12, 13
CH ₃ COCl (3.2 moles)	<i>t</i> -C ₄ H ₉ MgCl (2.46 moles)	CH ₃ CO ₂ CH(CH ₃)- <i>t</i> -C ₄ H ₉ (8%); CH ₃ CO- <i>t</i> -C ₄ H ₉ (17%); CH ₃ CO ₂ C ₂ H ₅ (9%); <i>i</i> -C ₄ H ₈ (6.6%); CH ₃ COCH = C(CH ₃) ₂ (6.6%); <i>i</i> -C ₄ H ₁₀ (23.6%); CO	14, 11
CH ₃ COCl* (345 g. 4.4 moles)	<i>t</i> -C ₄ H ₉ MgCl (2.72 moles)	CH ₃ CO- <i>t</i> -C ₄ H ₉ (10%); CH ₃ CO ₂ - <i>n</i> -C ₄ H ₉ (2%); CH ₃ COCH = C(CH ₃) ₂ (5%); CH ₃ CO ₂ CH(CH ₃)- <i>t</i> -C ₄ H ₉ (11%); <i>i</i> -C ₄ H ₈ (0.356 mole); <i>i</i> -C ₄ H ₁₀ (0.522 mole); CO (0.005 mole)	90
CH ₃ COCl	(CH ₃) ₃ SiCH ₂ MgCl	(CH ₃) ₂ CO; unidentified products	101
CH ₃ COCl (1 mole)	2-Thenyl-MgCl (0.246 mole)	2-Methyl-2-acetylthiophene (31-34%)	133

*Reaction in *n*-Bu₂O solution.

TABLE IX-II (Continued)

Halide	RMgX	Product(s)	Ref.
C₂H₅OCl (cont.)			
CH ₃ COCl (308 g.)	CH ₃ (<i>i</i> -C ₃ H ₇) CHMgBr (412 g.)	CH ₃ COCH(CH ₃)- <i>i</i> -C ₃ H ₇ (55 g., 9.3%)	15
CH ₃ COCl (2.2 moles)	<i>t</i> -C ₅ H ₁₁ MgCl (1.97 mole)	CH ₃ CO- <i>t</i> -C ₅ H ₁₁ (< 66.5 g.)	12
CH ₃ COCl (3.1 moles)	<i>t</i> -C ₅ H ₁₁ MgCl (1.99 mole)	CH ₃ CO- <i>t</i> -C ₅ H ₁₁ (96.6 g.)	12
CH ₃ COCl	<i>t</i> -C ₅ H ₁₁ MgCl	CH ₃ CO ₂ C ₂ H ₅ (4%); CH ₃ CO- <i>t</i> -C ₅ H ₁₁ (9%); CH ₃ COC(CH ₃)=C(CH ₃) ₂ (9%)	90
CH ₃ COCl	C ₆ H ₅ MgBr	C ₆ H ₅ CH=CH ₂	16
CH ₃ COCl	C ₆ H ₅ MgBr (2.5 equiv.)	CH ₃ (C ₆ H ₅) ₂ COH (39%)	17
CH ₃ COCl	2-Pyridylmethyl-MgX*	2-Pyridylacetone	131
CH ₃ COCl	2,5-Dimethylpyrrol-MgI	2,5-Dimethyl-3-acetylpyrrole (86%)	18
CH ₃ COCl	RC≡CMgX†	CH ₃ COC≡CR† (8-15% for chlorides and bromides; 0% for iodides)	102
CH ₃ COCl	CH ₃ (C ₂ H ₅) ₂ CMgCl	CH ₃ COC(C ₂ H ₅) ₂ CH ₃ (18%)	12
CH ₃ COCl	2,6-Cl ₂ C ₆ H ₃ CH ₂ MgCl	CH ₃ COC ₆ H ₂ -3,5-Cl ₂ -4-CH ₃	27
CH ₃ COCl	2-ClC ₆ H ₄ CH ₂ MgCl	CH ₃ COC ₆ H ₄ -2-CH ₃ -3-Cl	27
CH ₃ COCl (excess)	C ₆ H ₅ CH ₂ MgCl	CH ₃ COC ₆ H ₄ -2-CH ₃ (18%)	19,27
CH ₃ COCl (52 g.)	2-CH ₃ C ₆ H ₄ MgBr (114 g. C ₇ H ₇ Br)	CH ₃ COC ₆ H ₄ -2-CH ₃ (30%)	26
CH ₃ COCl	<i>n</i> -C ₄ H ₉ (CH ₃) ₂ CMgCl	CH ₃ COC(CH ₃) ₂ - <i>n</i> -C ₄ H ₉ (9%)	12
CH ₃ COCl (0.05, 0.075, and 0.10 mole)	C ₆ H ₅ CH(CO ₂ Na)MgX† (0.10 mole)	CH ₃ COCH ₂ C ₆ H ₅ (54%, 48%, and 42%); CH ₃ C[CH(C ₆ H ₅)CO ₂ H] ₂ OH (25%, 19.8%, and 25%)	20
CH ₃ COCl (28 ml.)	2-Thianaphthenylmethyl-MgCl (0.0277 mole)	2-Methyl-3-acetylthianaphthene (1.51 g., 29%)	129
CH ₃ COCl (15.7 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (40 g. C ₉ H ₁₁ Br)	CH ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃ (10%)	26

*X = Br, I.

†R = *n*-C₄H₉, *n*-C₃H₁₁; X = Cl, Br, I.

‡In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE IX-II (Continued)

Halide	RMgX	Product(s)	Ref.
C₂H₃OCl (<i>cont.</i>)			
CH ₃ COCl (19.5 g.)	1-C ₁₀ H ₇ MgBr (52 g. C ₁₀ H ₇ Br)	CH ₃ CO-1-C ₁₀ H ₇ (50%)	26
CH ₃ COCl	1-C ₁₀ H ₇ CH ₂ MgCl	1-C ₁₀ H ₇ CH = C(CH ₃)CH ₂ -1-C ₁₀ H ₇	21
CH ₃ COCl (5 g.)	2-C ₁₀ H ₇ CH ₂ MgBr (9 g. C ₁₁ H ₉ Br)	2-C ₁₀ H ₇ CH = C(CH ₃)CH ₂ -2-C ₁₀ H ₇ (4.5 g.)	21
CH ₃ COCl	(CH ₃) ₅ C ₆ MgBr	CH ₃ COC ₆ (CH ₃) ₅ (38%)	22,23
CH ₃ COCl (0.5 mole)	9-Fluorenyl-MgBr (0.11 mole)	9-Acetylfluorene (50%)	24
CH ₃ COCl (0.5 mole)	9-Phenanthryl-MgBr (0.11 mole)	9-Acetylphenanthrene (27%)	24
CH ₃ COCl	(C ₆ H ₅) ₃ CMgCl	"Passive"	25
CH ₃ COCl (1.6 g.)	2,4,6-(C ₆ H ₅) ₃ C ₆ H ₂ -MgBr (7.7 g. C ₂₄ H ₁₇ Br)	CH ₃ COC ₆ H ₂ -2,4,6-(C ₆ H ₅) ₃	3
C₂H₃O₂Cl			
CH ₃ OCOC ₂ H ₅ (9.4 g.)	Pyrryl-MgBr (6.7 g. C ₄ H ₅ N)	Methyl 2-pyrrolicarboxylate (85-90%)	100
CH ₃ OCOC ₂ H ₅ (10 g.)	2,6-Cl ₂ C ₆ H ₃ CH ₂ MgCl	2,6-Cl ₂ C ₆ H ₃ CH ₂ CO ₂ H; unidentified fraction	27
CH ₃ OCOC ₂ H ₅ (<i>excess</i>)	2-ClC ₆ H ₄ CH ₂ MgCl (0.032 mole)	2-ClC ₆ H ₄ CH ₂ CO ₂ H	27
CH ₃ OCOC ₂ H ₅ (10 g.)	C ₆ H ₅ CH ₂ MgCl (0.07 mole)	2-CH ₃ C ₆ H ₄ CO ₂ CH ₃ (equiv. 1 g. acid); C ₆ H ₅ CH ₂ CO ₂ H (trace)	27
CH ₃ OCOC ₂ H ₅ (9.45 g.)	<i>t</i> -C ₄ H ₉ (C ₆ H ₅) (<i>t</i> -C ₄ H ₉ C≡C)CMgBr (30.7 g., C ₁₇ H ₂₃ Br)	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)C = C = C(<i>t</i> -C ₄ H ₉)CO ₂ CH ₃ (18.5 g., 64%)	132
CH ₃ OCOC ₂ H ₅	(C ₆ H ₅) ₃ CMgBr	(C ₆ H ₅) ₃ CCO ₂ CH ₃ (66%)	28
C₃H₄OClBr			
CH ₃ CHBrCOCl	Pyrryl-MgX	"Bromopropionylpyrrole"	107
C₃H₅OCl			
C ₂ H ₃ COCl	Pyrryl-MgBr	2-Propionylpyrrole (50%)	29
C ₂ H ₅ COCl	Pyrryl-Mgl	2-Propionylpyrrole (50-60%)	9

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₅OCl (<i>cont.</i>)			
C ₂ H ₅ COCi	<i>t</i> -C ₄ H ₉ MgCl	(C ₂ H ₅) ₂ CO; C ₂ H ₅ CO- <i>t</i> -C ₄ H ₉ ; <i>n</i> -C ₃ H ₇ OH; C ₂ H ₅ CO ₂ H; C ₂ H ₅ CO ₂ CH(C ₂ H ₅) ₂ ; C ₂ H ₅ CO ₂ CH(C ₂ H ₅)- <i>t</i> -C ₄ H ₉	31
C ₂ H ₅ COCi	C ₆ H ₅ MgBr (2 equiv.)	C ₂ H ₅ (C ₆ H ₅) ₂ COH (57%)	17
C ₂ H ₅ COCi	2,5-Dimethylpyrryl-MgX	2,5-Dimethyl-3-propionylpyrrole	18
C₃H₅O₂Cl			
C ₂ H ₅ OCOCi	2-Furyl-MgI (1 equiv.)	Ethyl furoate	30
C ₂ H ₅ OCOCi (1 mole)	2-Thenyl-MgCl (0.179 mole)	2-Methyl-3-thiophenecarboxylic acid (17.85 g., 72%)	133
C ₂ H ₅ OCOCi	<i>t</i> -C ₅ H ₁₁ MgCl (1 equiv.)	<i>t</i> -C ₅ H ₁₁ CO ₂ C ₂ H ₅ (46%)	12
C ₂ H ₅ OCOCi	2,4-Dimethylpyrryl-MgX	Ethyl 3,5-dimethyl-2-pyrrolicarboxylate	104
C ₂ H ₅ OCOCi (50 g.)	C ₆ H ₅ CH ₂ MgCl (50 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CO ₂ C ₂ H ₅ (28 g., 43%); (C ₆ H ₅ CH ₂) ₃ COH (6 g.)	32
C ₂ H ₅ OCOCi	C ₆ H ₅ CH ₂ MgCl (1 equiv.)	2-CH ₃ C ₆ H ₄ CO ₂ H; C ₆ H ₅ CH ₂ CO ₂ H; (C ₆ H ₅ CH ₂) ₃ COH	27,33
C ₂ H ₅ OCOCi (1.07 mole)	<i>n</i> -C ₄ H ₉ (CH ₃) ₂ CMgCl (0.99 mole)	<i>n</i> -C ₄ H ₉ (CH ₃) ₂ CCO ₂ C ₂ H ₅ (47.1 g.)	12
C ₂ H ₅ OCOCi	C ₆ H ₅ CH(CO ₂ Na)MgCl*	C ₆ H ₅ CH(CO ₂ H)CO ₂ C ₂ H ₅ (73%)	97
C ₂ H ₅ OCOCi (3.0 g.)	(C ₈ H ₉ NO ₂ MgBr)MgBr [†]	Ethyl 3-methyl-4-(β-carboxyethyl)-2-pyrrolicarboxylate (45%)	105
C ₂ H ₅ OCOCi (33 ml.)	3-Thianaphthenylmethyl-MgCl (0.164 mole)	3-Methyl-2-thianaphthenecarboxylic acid (13.6 g., 43%)	134
C ₂ H ₅ OCOCi (2.6 g.)	(C ₉ H ₁₁ NO ₂ MgBr)MgBr [‡]	Ethyl 3-(β-carboxyethyl)-4,5-dimethyl-2-pyrrolicarboxylate (45%)	105

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

[†]From 2.2 g. "opsopyrrolicarboxylic acid."

[‡]From 2.0 g. "hemopyrrolicarboxylic acid."

TABLE IX-II (Continued)

Halide	RMgX	Product(s)	Ref.
C₃H₅O₂Cl (<i>cont.</i>)			
C ₂ H ₅ OCOCl	2-Phenylpyrryl-MgBr	Ethyl 5-phenylpyrrole-2-carboxylate	34
C ₂ H ₅ OCOCl (10 g.)	C ₁₀ H ₁₇ MgCl* (0.1 mole)	Recovered ester (55%); (C ₁₀ H ₁₇) CO ₂ C ₂ H ₅ (33%); (C ₁₀ H ₁₇) CH ₂ OH (12%); bornylene	106
C ₂ H ₅ OCOCl (69 g.)	Bornyl-MgCl† (0.5 mole)	(C ₁₀ H ₁₇)CO ₂ C ₂ H ₅ (95%)	106
C ₂ H ₅ OCOCl (20 g.)	Isobornyl-MgCl‡ (0.136 mole)	(C ₁₀ H ₁₇) CH ₂ OH (0.039 mole); bornylene	106
C ₂ H ₅ OCOCl (4 g.)	9-Phenanthryl-MgBr (6.45 g. C ₁₄ H ₉ Br)	Ethyl phenanthrene-9-carboxylate (> 50%)	35
C ₂ H ₅ OCOCl	(C ₆ H ₅) ₃ CMgBr	(C ₆ H ₅) ₃ CCO ₂ C ₂ H ₅ (72%)	28
C₄H₄O₂Cl₂ (—CH ₂ COCl) ₂	C ₆ H ₅ CH(CO ₂ Na)MgCl§ (2 equiv.)	(—CH ₂ CO ₂ H) ₂ (74%); (C ₆ H ₅ CH ₂ CO) ₂ O (40.7%); C ₆ H ₅ CH ₂ CO ₂ H (40.4%)	97
C₄H₅O₂Cl			
CH ₃ COCH ₂ COCl (12% excess)	<i>n</i> -C ₄ H ₉ MgBr (1 mole)	CH ₃ COCH ₂ CO- <i>n</i> -C ₄ H ₉ (1.4 g., 10%)	36
CH ₃ COCH ₂ COCl (35 g.)	<i>n</i> -C ₇ H ₁₅ MgBr (46 g. C ₇ H ₁₅ Br)	CH ₃ COCH ₂ CO- <i>n</i> -C ₇ H ₁₅ (16%)	36
CH ₃ COCH ₂ COCl	<i>n</i> -C ₈ H ₁₇ MgBr	CH ₃ COCH ₂ CO- <i>n</i> -C ₈ H ₁₇ (16%)	36
CH ₃ COCH ₂ COCl	CH ₃ (<i>n</i> -C ₆ H ₁₃)CHMgBr	CH ₃ COCH ₂ COCH(CH ₃)- <i>n</i> -C ₆ H ₁₃ (6%); <i>n</i> -C ₈ H ₁₈ (60%)	36

*From (+)- α -pinene hydrochloride; Rivière (106) concludes that this Grignard reagent is an equimolecular mixture of bornyl- and isobornylmagnesium chlorides.

†Prepared by refluxing in xylene for three hours at *ca.* 140° the Grignard reagent from (+)- α -pinene hydrochloride.

‡Prepared by partial (*ca.* 66%) carbonation of the Grignard reagent from (+)- α -pinene hydrochloride, which removes the more reactive bornylmagnesium chloride.

§In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE IX-II (Continued)

Halide	RMgX	Product (s)	Ref.
C₄H₅O₃Cl			
H ₅ C ₂ O ₂ CCOCl	RMgX* (2 equiv.)	H ₅ C ₂ O ₂ CCR ₂ OH* (35-40%)	37
H ₅ C ₂ O ₂ CCOCl	CH ₃ MgI (1 equiv.)	HO(CH ₃) ₂ CCO ₂ C ₂ H ₅ ; H ₅ C ₂ O ₂ CCO ₂ C(CH ₃) ₂ CO ₂ C ₂ H ₅	38
H ₅ C ₂ O ₂ CCOCl (1 mole)	C ₂ H ₅ MgI (1 mole)	HO(C ₂ H ₅) ₂ CCO ₂ C ₂ H ₅ (19 g.); H ₅ C ₂ O ₂ CCO ₂ C(C ₂ H ₅) ₂ CO ₂ C ₂ H ₅ (58 g.)	38
H ₅ C ₂ O ₂ CCOCl	Pyrrolyl-MgBr (1 equiv.)	Ethyl 2-pyrroleglyoxalate (91%)	108
H ₅ C ₂ O ₂ CCOCl	2,5-Dimethylpyrrolyl-MgI	Ethyl 2,5-dimethyl-3-pyrroleglyoxalate	18
H ₅ C ₂ O ₂ CCOCl (0.25 mole)	4-CH ₃ C ₆ H ₄ MgBr (0.50 mole)	HO(4-CH ₃ C ₆ H ₄) ₂ CCO ₂ C ₂ H ₅ (equiv. to 27 g. acid)	38
H ₅ C ₂ O ₂ CCOCl (6.8 g.)	Indolyl-MgBr (5.2 g. C ₈ H ₇ N)	Ethyl 3-indoleglyoxalate	109
H ₅ C ₂ O ₂ CCOCl	C ₆ H ₅ CH(CO ₂ Na)MgCl [†]	C ₆ H ₅ CH ₂ COCO ₂ C ₂ H ₅	97
C₄H₇OCl			
<i>n</i> -C ₃ H ₇ COCl	Pyrrolyl-MgI	2-Butyrylpyrrole (50-60%)	9
<i>n</i> -C ₃ H ₇ COCl (1 mole)	<i>t</i> -C ₄ H ₉ MgCl (4 moles)	<i>i</i> -C ₄ H ₈ (0.94 mole); <i>n</i> -C ₄ H ₉ OH (9%); <i>n</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (71%)	11
<i>n</i> -C ₃ H ₇ COCl (0.98 mole)	<i>t</i> -C ₄ H ₉ MgCl (4 moles)	(<i>t</i> -C ₄ H ₉ —) ₂ (20 g.); <i>n</i> -C ₄ H ₉ OH (6.5 g., 9%); <i>n</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (90.8 g., 71%); <i>i</i> -C ₄ H ₈ (94% on basis of <i>t</i> -C ₄ H ₉ Cl)	39
<i>n</i> -C ₃ H ₇ COCl (200 g.)	<i>t</i> -C ₄ H ₉ MgCl (1.86 mole)	<i>n</i> -C ₃ H ₇ CO- <i>t</i> -C ₄ H ₉ (21%); <i>n</i> -C ₃ H ₇ CO ₂ <i>n</i> - C ₄ H ₉ (11.6%); <i>n</i> -C ₃ H ₇ CO ₂ CH (<i>n</i> -C ₃ H ₇)- <i>t</i> -C ₄ H ₉ (36.8%)	90
<i>n</i> -C ₃ H ₇ COCl	C ₆ H ₅ MgBr (2.5 equiv.)	C ₂ H ₅ CH = C(C ₆ H ₅) ₂ (84%)	17

*R = CH₃, C₂H₅, *i*-C₅H₁₁, C₆H₅, 4-CH₃C₆H₄.

[†]In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE IX-II (Continued)

Halide	RMgX	Product (s)	Ref.
C₄H₇OCl (cont.)			
<i>i</i> -C ₃ H ₇ COCl	CH ₃ MgCl (1 equiv.)	CH ₃ CO- <i>i</i> -C ₃ H ₇ (7.6%); <i>i</i> -C ₃ H ₇ (CH ₃) ₂ COH	40,123
<i>i</i> -C ₃ H ₇ COCl	<i>n</i> -C ₃ H ₇ MgCl (1 equiv.)	<i>n</i> -C ₃ H ₇ CO- <i>i</i> -C ₃ H ₇ (7.6%); <i>i</i> -C ₃ H ₇ (CH ₃) ₂ COH	40,123
<i>i</i> -C ₃ H ₇ COCl	<i>i</i> -C ₃ H ₇ MgCl (1 equiv.)	(<i>i</i> -C ₃ H ₇) ₂ CO; C ₃ H ₆ ; (<i>i</i> -C ₃ H ₇) ₂ CHOH; (<i>i</i> -C ₃ H ₇) ₃ COH	40,123
<i>i</i> -C ₃ H ₇ COCl (0.84 mole)	<i>t</i> -C ₄ H ₉ MgCl (4.2 moles)	(<i>t</i> -C ₄ H ₉ —) ₂ (2.2 g.); <i>i</i> -C ₄ H ₉ OH (12.5 g.); <i>i</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (82.0 g.); <i>i</i> -C ₄ H ₈ (<i>ca.</i> 1.3 mole)	39,11
<i>i</i> -C ₃ H ₇ COCl	<i>t</i> -C ₄ H ₉ MgCl (1 equiv.)	<i>i</i> -C ₃ H ₇ CO- <i>t</i> -C ₄ H ₉ (35%); <i>i</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉) ₂ COH	40,123
<i>i</i> -C ₃ H ₇ COCl* (20 moles)	<i>t</i> -C ₄ H ₉ MgCl (20 moles)	<i>i</i> -C ₃ H ₇ CO- <i>t</i> -C ₄ H ₉ (87%); <i>i</i> -C ₃ H ₇ CO ₂ - <i>i</i> -C ₄ H ₉ (5%); <i>i</i> -C ₃ H ₇ CHO (0.1%); <i>i</i> -C ₄ H ₉ OH (2%)	41
<i>i</i> -C ₃ H ₇ COCl (1.86 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.86 mole)	<i>i</i> -C ₃ H ₇ CO- <i>t</i> -C ₄ H ₉ (19%, crude); <i>i</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (17.7%); <i>i</i> -C ₃ H ₇ CO ₂ CH(<i>i</i> -C ₃ H ₇)- <i>t</i> -C ₄ H ₉ (45%)	90
<i>i</i> -C ₃ H ₇ COCl (160 g., 1.5 mole)	<i>t</i> -C ₅ H ₁₁ MgCl (1.3 mole)	<i>i</i> -C ₃ H ₇ CO ₂ - <i>i</i> -C ₄ H ₉ (44%)	90
<i>i</i> -C ₃ H ₇ COCl	C ₆ H ₅ MgX (1 equiv.)	<i>i</i> -C ₃ H ₇ COC ₆ H ₅ (21%)	40
<i>i</i> -C ₃ H ₇ COCl	2-CH ₃ C ₆ H ₄ MgBr (1 equiv.)	<i>i</i> -C ₃ H ₇ COC ₆ H ₄ -2-CH ₃ (67%); <i>i</i> -C ₃ H ₇ (2-CH ₃ C ₆ H ₄) ₂ COH	40,123
<i>i</i> -C ₃ H ₇ COCl	2-CH ₃ OC ₆ H ₄ MgX (1 equiv.)	<i>i</i> -C ₃ H ₇ COC ₆ H ₄ -2-OCH ₃ (63%)	40,123
<i>i</i> -C ₃ H ₇ COCl (0.1 mole)	C ₆ H ₅ CH(CO ₂ Na)MgX† (0.2 mole)	<i>i</i> -C ₃ H ₇ COCH ₂ C ₆ H ₅ (10.7 g., 66%); <i>i</i> -C ₃ H ₇ C[CH(C ₆ H ₅)CO ₂ H] ₂ OH (5 g., 14.6%)	20

*Reaction at 14–17° in copper vessel; reverse order of addition.

†In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135–54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₇OCl (<i>cont.</i>)			
<i>i</i> -C ₃ H ₇ COCl	2,6-(CH ₃) ₂ C ₆ H ₃ MgX (1 equiv.)	<i>i</i> -C ₃ H ₇ COC ₆ H ₃ -2,6-(CH ₃) ₂ (65%)	40,123
<i>i</i> -C ₃ H ₇ COCl	1-C ₁₀ H ₇ MgBr (1 equiv.)	<i>i</i> -C ₃ H ₇ CO-1-C ₁₀ H ₇ (63%)	40,123
<i>i</i> -C ₃ H ₇ COCl	9-Phenanthryl-MgX (1 equiv.)	9-Isobutyrylphenanthrene (61%)	40
C₄H₇O₂Cl			
<i>n</i> -C ₃ H ₇ OCOC1	Pyrryl-MgBr	<i>n</i> -Propyl 2-pyrrolicarboxylate (85-90%)	100
C₅H₃OClS			
2-Thenoyl chloride	Pyrryl-MgBr	2-Thienyl 2-pyrryl ketone	87
2-Thenoyl chloride	Indolyl-MgBr	2-Thienyl 3-indolyl ketone	87
C₅H₄OClN			
2-Pyrrolicarbonyl chloride	Pyrryl-MgBr	2-Pyrryl ketone (11%)	130,108
C₅H₇O₃Cl			
H ₅ C ₂ O ₂ CCH ₂ COCl	Pyrryl-MgBr	Ethyl β-oxo-2-pyrrolicpropionate	100
C₅H₉OCl			
<i>i</i> -C ₄ H ₉ COCl (0.1 mole)	C ₆ H ₅ CH(CO ₂ Na)MgX* (0.2 and 0.1 mole)	<i>i</i> -C ₄ H ₉ COCH ₂ C ₆ H ₅ (66% and 48%); <i>i</i> -C ₄ H ₉ C[CH(C ₆ H ₅)CO ₂ H] ₂ OH (7% and 6%)	20
<i>t</i> -C ₄ H ₉ COCl (2.54 moles)	C ₂ H ₅ MgBr (6.1 moles)	<i>t</i> -C ₄ H ₉ (C ₂ H ₅) ₂ COH (26.1%); C ₂ H ₅ (<i>t</i> -C ₄ H ₉)CHOH (60.0%)	43

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₇OCl (cont.)			
<i>t</i> -C ₄ H ₉ COCl (1.5 mole)	C ₂ H ₅ MgBr (5 moles C ₂ H ₅ Br)	<i>t</i> -C ₄ H ₉ (C ₂ H ₅) ₂ COH (20%); C ₂ H ₅ (<i>t</i> -C ₄ H ₉)CHOH (69%); C ₂ H ₅ OH; residue (10 g.)	45
<i>t</i> -C ₄ H ₉ COCl (1.5 mole)	<i>n</i> -C ₃ H ₇ MgBr (4.5 moles C ₃ H ₇ Br)	<i>t</i> -C ₄ H ₉ CH ₂ OH (20%); <i>n</i> -C ₃ H ₇ OH; <i>n</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (76%)	45
<i>t</i> -C ₄ H ₉ COCl (1.5 mole)	<i>i</i> -C ₃ H ₇ MgBr (4.5 moles)	<i>i</i> -C ₃ H ₇ OH; <i>t</i> -C ₄ H ₉ CH ₂ OH (23%); <i>i</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (53%)	45
<i>t</i> -C ₄ H ₉ COCl (ca. 1 mole)	<i>n</i> -C ₄ H ₉ MgBr (4 moles C ₄ H ₉ Br)	<i>t</i> -C ₄ H ₉ CH ₂ OH (27-28%); <i>n</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉)CHOH (69-71%)	10, 11, 45
<i>t</i> -C ₄ H ₉ COCl (1.5 mole)	<i>i</i> -C ₄ H ₉ MgBr (4.5 moles)	<i>i</i> -C ₄ H ₉ OH; <i>t</i> -C ₄ H ₉ CH ₂ OH (61%); <i>i</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉)CHOH (26%)	45
<i>t</i> -C ₄ H ₉ COCl (55.8 g., 0.465 mole)	<i>i</i> -C ₄ H ₉ MgI (0.98 mole)	<i>t</i> -C ₄ H ₉ CH ₂ OH (74%)	90
<i>t</i> -C ₄ H ₉ COCl (302 g., 2.5 moles)	<i>t</i> -C ₄ H ₉ MgCl (7.0 moles)	<i>t</i> -C ₄ H ₉ CH ₂ OH; (<i>t</i> -C ₄ H ₉) ₂ CO; <i>t</i> -C ₄ H ₉ CHO (1%)	90
<i>t</i> -C ₄ H ₉ COCl* (966.5 g.)	<i>t</i> -C ₄ H ₉ MgCl (1.5 mole)	(<i>t</i> -C ₄ H ₉) ₂ CO (67.4 g., 32%); mixture (<i>t</i> -C ₄ H ₉) ₂ CO and <i>t</i> -C ₄ H ₉ CO ₂ CH ₂ - <i>t</i> - C ₄ H ₉ (?) (50.3 g.); <i>t</i> -C ₄ H ₉ CO ₂ CH ₂ - <i>t</i> - C ₄ H ₉ (14.1 g.); (<i>t</i> -C ₄ H ₉ CO) ₂ O (15.3 g.); <i>i</i> -C ₄ H ₉ (17% on basis of G.r.).	39
<i>t</i> -C ₄ H ₉ COCl [†] (1.1 mole)	<i>t</i> -C ₄ H ₉ MgCl (3.9 moles)	(<i>t</i> -C ₄ H ₉ —) ₂ (6 g., crude); <i>t</i> -C ₄ H ₉ CH ₂ OH 88 g., 94%); (<i>t</i> -C ₄ H ₉) ₂ CHOH (1.8 g., 1.5%); <i>i</i> -C ₄ H ₉ (ca. 2 moles)	39, 11
<i>t</i> -C ₄ H ₉ COCl (0.22 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.1 mole)	<i>i</i> -C ₄ H ₉ (0.27 mole); <i>t</i> -C ₄ H ₉ CH ₂ OH (45%); <i>t</i> -C ₄ H ₉ CO ₂ CH ₂ - <i>t</i> -C ₄ H ₉ (45%)	11

*Slow (17 hours) addition of filtered Grignard solution to Et₂O-chloride solution at -10°; warming to 50°.

†Gradual (4.5 hours) addition of chloride to filtered Grignard solution at ca. 40°; overnight standing.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₉OCl (<i>cont.</i>)			
<i>t</i> -C ₄ H ₉ COCl (8 moles)	<i>t</i> -C ₄ H ₉ MgCl (1.5 mole)	<i>i</i> -C ₄ H ₈ (17%); <i>t</i> -C ₄ H ₉ CO ₂ CH ₂ - <i>t</i> -C ₄ H ₉ (8%); (<i>t</i> -C ₄ H ₉) ₂ CO (32%); <i>t</i> -C ₄ H ₉ CO ₂ H (6.2 moles)	11
<i>t</i> -C ₄ H ₉ COCl (1.5 mole)	<i>n</i> -C ₅ H ₁₁ MgBr (4.5 moles C ₅ H ₁₁ Br)	<i>t</i> -C ₄ H ₉ CH ₂ OH (20%); <i>t</i> -C ₄ H ₉ (<i>n</i> -C ₅ H ₁₁)CHOH (75%)	45
<i>t</i> -C ₄ H ₉ COCl (1.5 mole)	<i>i</i> -C ₅ H ₁₁ MgBr (4.5 moles)	<i>i</i> -C ₅ H ₁₁ OH; C ₁₆ H ₃₂ (7%); <i>t</i> -C ₄ H ₉ CH ₂ OH (15%); <i>t</i> -C ₄ H ₉ (<i>i</i> -C ₅ H ₁₁)CHOH (71%)	45
<i>t</i> -C ₄ H ₉ COCl (0.5 mole)	<i>t</i> -C ₅ H ₁₁ MgCl (1.17 mole)	<i>t</i> -C ₄ H ₉ CH ₂ OH (97.5%)	90
<i>t</i> -C ₄ H ₉ COCl (129 g.)	C ₆ H ₅ MgBr (1050 ml., 1.6 <i>N</i>)	<i>t</i> -C ₄ H ₉ COC ₆ H ₅ (116 g., 67%)	132
C₅H₉O₂Cl			
<i>i</i> -C ₄ H ₉ OCOC ₂ H ₅	Pyrryl-MgBr	Isobutyl 2-pyrrolecarboxylate (85-90%)	100
C₆H₅OClBr			
5-Bromonicotinyl chloride	CH ₃ MgBr	3-Acetyl-5-bromopyridine (15%)	110
5-Bromonicotinyl chloride	CH ₃ MgI (3.5 equiv.)	2-(5-Bromo-3-pyridyl)-2-propanol	110
C₆H₅OCl₂			
5-Chloronicotinyl chloride (20.0 g., 0.12 mole)	CH ₃ MgI (3.5 equiv.)	2-(5-Chloro-3-pyridyl)-2-propanol (14.2 g., 73%)	110
C₆H₅O₂Cl₂			
(—CH ₂ CH ₂ COCl) ₂	C ₆ H ₅ CH(CO ₂ Na)MgCl* (2 equiv.)	(—CH ₂ CH ₂ CO ₂ H) ₂ (82.2%); (C ₆ H ₅ CH ₂ CO) ₂ O (16.6%); C ₆ H ₅ CH ₂ CO ₂ H (58.0%)	97

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₆H₉OC₂Cl			
H ₂ C=CH(CH ₂) ₃ COCl (30 g.)	CH ₃ MgI (33 g. CH ₃ I)	CH ₃ CO(CH ₂) ₃ CH=CH ₂ (48%)	48
C₆H₅O₂Cl			
H ₅ C ₂ O ₂ C(CH ₂) ₂ COCl	C ₆ H ₅ CH(CO ₂ Na)MgCl*	H ₅ C ₂ O ₂ C(CH ₂) ₂ COCH ₂ C ₆ H ₅	97
C₆H₁₁OC₂Cl			
<i>i</i> -C ₅ H ₁₁ COCl	<i>t</i> -C ₄ H ₉ MgCl (1 equiv.)	(<i>i</i> -C ₅ H ₁₁) ₂ CO; <i>i</i> -C ₅ H ₁₁ CO ₂ - <i>i</i> -C ₆ H ₁₃	31
<i>t</i> -C ₄ H ₉ CH ₂ COCl [†] (1.3 mole)	C ₂ H ₅ MgBr (5 moles C ₂ H ₅ Br)	<i>t</i> -C ₄ H ₉ CH ₂ (C ₂ H ₅) ₂ COH (118.5 g., crude); C ₂ H ₅ OH	44
<i>t</i> -C ₄ H ₉ CH ₂ COCl [‡] (1.86 mole)	C ₂ H ₅ MgBr (1.84 mole)	<i>t</i> -C ₄ H ₉ CH ₂ CO ₂ C ₂ H ₅ ; <i>t</i> -C ₄ H ₉ CH ₂ CO ₂ CH(C ₂ H ₅)CH ₂ - <i>t</i> -C ₄ H ₉ (7%); <i>t</i> -C ₄ H ₉ CH ₂ COC ₂ H ₅ (51%); <i>t</i> -C ₄ H ₉ CH ₂ (C ₂ H ₅) ₂ COH (?); <i>t</i> -C ₄ H ₉ CH ₂ CO ₂ H	46
<i>t</i> -C ₄ H ₉ CH ₂ COCl [§] (1.7 mole)	<i>n</i> -C ₃ H ₇ MgBr (4.5 moles)	<i>n</i> -C ₃ H ₇ OH; <i>n</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (24.4%); <i>t</i> -C ₄ H ₉ CH ₂ (<i>n</i> -C ₃ H ₇) ₂ COH	44
<i>t</i> -C ₄ H ₉ CH ₂ COCl [¶] (1.94 mole)	<i>n</i> -C ₃ H ₇ MgBr (1.85 mole)	<i>t</i> -C ₄ H ₉ CH ₂ CO ₂ C ₂ H ₅ ; <i>t</i> -C ₄ H ₉ CH ₂ CO- <i>n</i> -C ₃ H ₇ (36.7%); <i>t</i> -C ₄ H ₉ CH ₂ CO ₂ - CH(<i>n</i> -C ₃ H ₇)CH ₂ - <i>t</i> -C ₄ H ₉ (20%); <i>t</i> -C ₄ H ₉ CH ₂ CO ₂ H; C ₁₂ H ₂₄	46

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

[†]Gradual (1.25 hour) addition of chloride to Grignard solution.

[‡]Gradual (50 minutes) addition of filtered Grignard solution to Et₂O-chloride solution; overnight standing.

[§]Gradual (1.7 hour) addition of chloride to Grignard solution.

[¶]Gradual (45 minutes) addition of filtered Grignard solution to Et₂O-chloride solution; overnight standing.

TABLE IX-II (Continued)

Halide	RMgX	Product(s)	Ref.
C₆H₁₁OCl (cont.)			
<i>t</i> -C ₄ H ₉ CH ₂ COCl (1 mole)	<i>i</i> -C ₃ H ₇ MgBr (4 moles)	<i>t</i> -C ₄ H ₉ CH ₂ CO- <i>i</i> -C ₃ H ₇ (32.7%); <i>i</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (26.7%)	43
<i>t</i> -C ₄ H ₉ CH ₂ COCl* (1.7 mole)	<i>n</i> -C ₄ H ₉ MgBr (4.5 moles)	<i>n</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (54.9 g., 20.5%); <i>t</i> -C ₄ H ₉ CH ₂ - (<i>n</i> -C ₄ H ₉) ₂ COH; <i>n</i> -C ₄ H ₉ OH	44
<i>t</i> -C ₄ H ₉ CH ₂ COCl† (2.18 moles)	<i>n</i> -C ₄ H ₉ MgBr (2.01 moles)	<i>t</i> -C ₄ H ₉ CH ₂ CO ₂ C ₂ H ₅ ; <i>t</i> -C ₄ H ₉ CH ₂ CO- <i>n</i> -C ₄ H ₉ (34%); <i>t</i> -C ₄ H ₉ CH ₂ CO ₂ CH- (<i>n</i> -C ₄ H ₉)CH ₂ - <i>t</i> -C ₂ H ₉ (23%); <i>t</i> -C ₄ H ₉ CH ₂ CO ₂ H	46
<i>t</i> -C ₄ H ₉ CH ₂ COCl (0.5 mole)	<i>i</i> -C ₄ H ₉ MgBr (1.45 mole)	<i>t</i> -C ₄ H ₉ CH ₂ CO- <i>i</i> -C ₄ H ₉ (15.7 g., 20.1%); <i>i</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (38.6 g., 48.9%); <i>t</i> -C ₄ H ₉ CH ₂ (<i>i</i> -C ₄ H ₉) ₂ COH (14.7 g., 13.8%)	46
<i>t</i> -C ₄ H ₉ CH ₂ COCl (134.5 g., 1 mole)	<i>t</i> -C ₄ H ₉ MgCl (2.87 moles)	<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ OH (5.0%); <i>t</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (48.5%)	90
<i>t</i> -C ₄ H ₉ CH ₂ COCl‡ (2.5 moles)	<i>t</i> -C ₄ H ₉ MgCl (5.4 moles)	<i>t</i> -C ₄ H ₉ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (282.3 g., 71%); <i>t</i> -C ₄ H ₉ CH ₂ CH ₂ OH (1%); <i>t</i> -C ₄ H ₉ CH ₂ CO ₂ CH(<i>t</i> -C ₄ H ₉)CH ₂ - <i>t</i> - C ₄ H ₉ (5%)	47
<i>t</i> -C ₄ H ₉ CH ₂ COCl§ (0.95 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.0 mole)	<i>t</i> -C ₄ H ₉ CH ₂ CO- <i>t</i> -C ₄ H ₉ (75.4 g., 51%); <i>t</i> -C ₄ H ₉ CH ₂ CO ₂ CH(<i>t</i> -C ₄ H ₉)CH ₂ - <i>t</i> - C ₄ H ₉ (17%)	44

*Gradual (1.5 hour) addition of chloride to Grignard solution.

†Gradual (80 minutes) addition of filtered Grignard solution to Et₂O-chloride solution; overnight standing.

‡Slow (3 days) addition of Et₂O-chloride solution to Grignard solution; four days reflux.

§Slow (36 hours) addition of filtered Grignard solution to Et₂O-chloride solution.

TABLE IX-II (Continued)

Halide	RMgX	Product(s)	Ref.
$C_6H_{11}OCl$ (cont.)			
$t-C_4H_9CH_2COCl^*$ (1.5 mole)	$n-C_5H_{11}MgBr$ (4.1 moles)	$n-C_5H_{11}(t-C_4H_9CH_2)CHOH$ (19.3%); $C_{16}H_{32}$ (0.71 mole); $n-C_5H_{11}OH$	44
$t-C_4H_9CH_2COCl^\dagger$ (2.0 moles)	$n-C_5H_{11}MgBr$ (1.9 mole)	$t-C_4H_9CH_2CO-n-C_5H_{11}$ (2.9%); $t-C_4H_9CH_2CO_2CH(n-C_5H_{11})CH_2-t-C_4H_9$ (21%); $C_{16}H_{32}$; $t-C_4H_9CH_2CO_2C_2H_5$; $t-C_4H_9CH_2CO_2H$	46
$t-C_4H_9CH_2COCl$ (102.8 g., 0.85 mole)	$t-C_4H_9CH_2MgCl$ (1.13 mole)	$(t-C_4H_9CH_2)_2CO$ (87%); $t-C_4H_9CH_2OH$	90
$(C_2H_5)_2CHCOCl$ (134.5 g., 1 mole)	$t-C_4H_9MgCl$ (2.12 moles, 0.98M)	$(C_2H_5)_2CHCH_2OH$ (18.6%); $t-C_4H_9[(C_2H_5)_2CH]CHOH$ (68.6%)	90
$(C_2H_5)_2CHCOCl$ (134.5 g., 1 mole)	$t-C_4H_9MgCl$ (2.12 moles, 2.06M)	$(C_2H_5)_2CHCH_2OH$ (24.6%); $t-C_4H_9[(C_2H_5)_2CH]CHOH$ (63.0%)	90
$(C_2H_5)_2CHCOCl$ (134.5 g., 1 mole)	$t-C_4H_9MgCl$ (2.12 moles, 3.78M)	$(C_2H_5)_2CHCH_2OH$ (28.7%); $t-C_4H_9[(C_2H_5)_2CH]CHOH$ (45.0%)	90
$(C_2H_5)_2CHCOCl$ (134.5 g., 1 mole)	$t-C_4H_9MgCl$ (2.56 moles, 1.07M)	$(C_2H_5)_2CHCH_2OH$ (20.0%); $t-C_4H_9[(C_2H_5)_2CH]CHOH$ (63.3%)	90
$(C_2H_5)_2CHCOCl$ (134.5 g., 1 mole)	$t-C_4H_9MgCl$ (2.56 moles, 2.17M)	$(C_2H_5)_2CHCH_2OH$ (25.3%); $t-C_4H_9[(C_2H_5)_2CH]CHOH$ (60.5%)	90
$(C_2H_5)_2CHCOCl$ (134.5 g., 1 mole)	$t-C_4H_9MgCl$ (2.56 moles, 3.95M)	$(C_2H_5)_2CHCH_2OH$ (30.0%); $t-C_4H_9[(C_2H_5)_2CH]CHOH$ (43.2%)	90
$(C_2H_5)_2CHCOCl$ (134.5 g., 1 mole)	$t-C_4H_9MgCl$ (3.70 moles, 1.85M)	$(C_2H_5)_2CHCH_2OH$ (21.7 g.); $t-C_4H_9[(C_2H_5)_2CH]CHOH$ (88.3 g.); $(t-C_4H_9-)_2$ (21.7 g.)	90
$(C_2H_5)_2CHCOCl$ (134.5 g., 1 mole)	$t-C_5H_{11}MgCl$ (3.15 moles, 1.90M)	$(C_2H_5)_2CHCH_2OH$ (74.5%); $t-C_5H_{11}[(C_2H_5)_2CH]CHOH$ (7.8%)	90

*Gradual (1.3 hour) addition of chloride to Grignard solution.

†Gradual (50 minutes) addition of filtered Grignard solution to Et_2O -chloride solution.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₁OCl (<i>cont.</i>)			
<i>t</i> -C ₅ H ₁₁ COCl (1 mole)	<i>i</i> -C ₃ H ₇ MgBr (4.16 moles)	<i>t</i> -C ₃ H ₁₁ CH ₂ OH (30 g., 29.4%); <i>i</i> -C ₃ H ₇ (<i>t</i> -C ₅ H ₁₁)CHOH (76 g., 49.3%)	43
C₆H₁₁OBr			
(C ₂ H ₅) ₂ CHCOBr (1.24 mole)	<i>t</i> -C ₄ H ₉ MgCl (3.03 moles)	(C ₂ H ₅) ₂ CHCH ₂ OH (27.7%); <i>t</i> -C ₄ H ₉ [(C ₂ H ₅) ₂ CH]CHOH (60.0%)	90
C₆H₁₁OI			
(C ₂ H ₅) ₂ CHCOI (277 g., crude)	<i>t</i> -C ₄ H ₉ MgCl (3.27 moles)	(C ₂ H ₅) ₂ CHCH ₂ OH (12%); <i>t</i> -C ₄ H ₉ [(C ₂ H ₅) ₂ CH]CHOH (36%); high-boiling material	90
C₇H₂OClBr₃			
2,4,6-Br ₃ C ₆ H ₂ COCl (5 g.)	CH ₃ Mgl (75 ml., 2.2M)	2,4,6-Br ₃ C ₆ H ₂ COCH ₃ (2.2 g., 46%)	49
2,4,6-Br ₃ C ₆ H ₂ COCl	CH ₃ MgBr (2 equiv.)	(2,4,6-Br ₃ C ₆ H ₂ CO) ₂ CH ₂ (38%); 2,4,6-Br ₃ C ₆ H ₂ COCH ₃ (16%)	49
C₇H₂OCl₄			
2,4,6-Cl ₃ C ₆ H ₂ COCl	CH ₃ MgX* (1-2 equiv.)	(2,4,6-Cl ₃ C ₆ H ₂ CO) ₂ CH ₂ (30-50%)	50,49
2,4,6-Cl ₃ C ₆ H ₂ COCl (12.3 g.)	CH ₃ MgCl (25 ml., 2M)	2,4,6-Cl ₃ C ₆ H ₂ COCH ₃ (50%)	111
C₇H₄OClBr			
4-BrC ₆ H ₄ COCl (0.1 mole)	C ₆ H ₅ CH(CO ₂ Na)MgX [†] (0.2 mole)	4-BrC ₆ H ₄ COCH ₂ C ₆ H ₅ (16 g., 58%); 4-BrC ₆ H ₄ C[CH(C ₆ H ₅)CO ₂ H] ₂ OH (6.2 g., 14%)	20

*X = Cl, Br, I.

[†]In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₄O₃Cl₂S			
2-ClO ₂ SC ₆ H ₄ -1-COCl (10 g.)	C ₆ H ₅ MgBr (3.5 equiv.)	2-C ₆ H ₅ O ₂ SC ₆ H ₄ -1-C(C ₆ H ₅) ₂ OH	51
C₇H₅OCl			
C ₆ H ₅ COC1	CH ₃ MgI	C ₆ H ₅ (CH ₃) ₂ COH	8
C ₆ H ₅ COC1	C ₂ H ₅ MgBr (2.5 equiv.)	C ₆ H ₅ (C ₂ H ₅) ₂ COH (93%)	17
C ₆ H ₅ COC1	<i>n</i> -C ₃ H ₇ MgBr (2.5 equiv.)	C ₆ H ₅ (<i>n</i> -C ₃ H ₇) ₂ COH (81%)	17
C ₆ H ₅ COC1	Pyrryl-MgI	2-Benzoylpyrrole (<i>ca.</i> 80%)	9
C ₆ H ₅ COC1	C ₆ H ₅ MgX* (1 equiv.)	(C ₆ H ₅) ₂ CO (Cl, 48%; Br, 55%; I, 68.5%); (C ₆ H ₅) ₃ COH	52
C ₆ H ₅ COC1 (0.5 mole)	C ₆ H ₅ MgBr (0.5 mole)	(C ₆ H ₅) ₂ CO (29%); (C ₆ H ₅) ₃ COH (38%); (C ₆ H ₅ —) ₂ (5.4%)	17
C ₆ H ₅ COC1 (0.17 mole)	C ₆ H ₅ MgBr (0.5 mole)	(C ₆ H ₅) ₂ CO (91.5%); (C ₆ H ₅ —) ₂ (7%)	17
C ₆ H ₅ COC1 (0.5 mole)	C ₆ H ₅ MgBr (0.3 mole)	(C ₆ H ₅) ₂ CO (45.2%); (C ₆ H ₅) ₃ COH (32.6%); (C ₆ H ₅ —) ₂ (10.8%)	17
C ₆ H ₅ COC1	C ₆ H ₅ OC≡CMgBr (?)	(C ₆ H ₅ CO ₂ C ₆ H ₅ (38%); C ₆ H ₅ OH (10%); tar	42
C ₆ H ₅ COC1 (0.1, 0.1, and 0.075 mole)	C ₆ H ₅ CH(CO ₂ Na)MgX [†] (0.2, 0.1, and 0.1 mole)	C ₆ H ₅ COCH ₂ C ₆ H ₅ (75%, 48%, and 60%); C ₆ H ₅ ClCH(C ₆ H ₅)CO ₂ H] ₂ OH (16%, 17%, and 18%)	20
C ₆ H ₅ COCl	4-CH ₃ C ₆ H ₄ SO ₂ CH(MgBr) ₂	4-CH ₃ C ₆ H ₄ SO ₂ CH(COC ₆ H ₅) ₂	128
C ₆ H ₅ COCl	2,3-(CH ₃) ₂ C ₆ H ₃ MgBr	2,3-(CH ₃) ₂ C ₆ H ₃ COC ₆ H ₅	88
C ₆ H ₅ COCl	1-C ₁₀ H ₇ MgBr	C ₆ H ₅ CO-1-C ₁₀ H ₇	53
C ₆ H ₅ COCl	(CH ₃) ₅ C ₆ MgBr	C ₆ H ₅ COC ₆ (CH ₃) ₅ (35%)	54
C ₆ H ₅ COCl	(CH ₃) ₅ C ₆ MgBr	C ₆ H ₅ COC ₆ (CH ₃) ₅ (5%)	22,23
C ₆ H ₅ COCl	2,5-Diphenyl-3-furyl-MgBr	2,5-Diphenyl-3-benzoylfuran (32%)	125

*X = Cl, Br, I.

[†]In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₅OCl (<i>cont.</i>)			
C ₆ H ₅ COCl	(C ₆ H ₅ SO ₂) ₂ C(MgBr) ₂	(C ₆ H ₅ SO ₂) ₂ CHCOC ₆ H ₅	126
C ₆ H ₅ COCl	(4-CH ₃ C ₆ H ₄ SO ₂) ₂ CHMgBr	(4-CH ₃ C ₆ H ₄ SO ₂) ₂ CHCOC ₆ H ₅ (81%)	127
C ₆ H ₅ COCl (2 ml.)	α -Phenyl- β -o-biphenylenevinyl- MgBr (5 g. C ₂₀ H ₁₃ Br)	α -Phenyl- β -o-biphenyleneacrylophenone	56
C ₆ H ₅ COCl (4 ml.)	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)MgBr (10 g. C ₂₀ H ₁₃ Br)	C ₆ H ₅ COC(C ₆ H ₅)=C(C ₆ H ₅) ₂ (5 g.)	55
C ₆ H ₅ COCl	2,4,6-(C ₆ H ₅) ₃ C ₆ H ₂ MgBr	C ₆ H ₅ COC ₆ H ₂ -2,4,6-(C ₆ H ₅) ₃ (60%)	3
C₇H₅OBr			
C ₆ H ₅ COBr (0.2 mole)	C ₆ H ₅ MgCl (0.5 mole)	(C ₆ H ₅) ₃ COH (51 g., 98%, crude)	17
C ₆ H ₅ COBr	C ₆ H ₅ OC \equiv CMgBr	C ₆ H ₅ CO ₂ C ₆ H ₅ (26%); C ₆ H ₅ OH (2%); tar	42
C₇H₉OCl			
1-Cyclohexenecarboxylic acid chloride	(CH ₂) ₅ CHMgBr	Cyclohexyl 1-cyclohexenyl ketone (40-60%)*	57
C₇H₁₀O₃ClBr			
C ₂ H ₅ CBr(CO ₂ C ₂ H ₅)COCl (8.0 g.)	C ₆ H ₅ MgBr (13.0 g. C ₆ H ₅ Br)	C ₆ H ₅ COC(C ₂ H ₅)=C(C ₆ H ₅) ₂ (0.1 g.)	112
C₇H₁₁OCl			
(CH ₂) ₅ CHCOCl	CH ₃ Mgl	(CH ₂) ₅ CHCOCH ₃ (40-60%)*	57
(CH ₂) ₅ CHCOCl	<i>n</i> -C ₃ H ₇ MgBr	(CH ₂) ₅ CHCO- <i>n</i> -C ₃ H ₇ (40-60%)*	57
(CH ₂) ₅ CHCOCl	<i>n</i> -C ₅ H ₇ MgBr	(CH ₂) ₅ CHCO- <i>n</i> -C ₃ H ₇ (80%); <i>n</i> -C ₃ H ₇ OH; <i>n</i> -C ₄ H ₉ CH(CH ₂) ₅	113

* Yields of 40-60% are reported for a series of reactions investigated.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₁OCl (<i>cont.</i>)			
(CH ₂) ₅ CHCOCl	(CH ₂) ₅ CHMgBr	[(CH ₂) ₅ CH] ₂ CO (60-70%); [(CH ₂) ₅ CH] ₂ CH ₂ ; (CH ₂) ₅ CHOH; cyclohexene	113
(CH ₂) ₄ C(CH ₃)COCl (29.2 g.)	CH ₃ MgI (34.1 g. CH ₃ I)	(CH ₂) ₄ C(CH ₃)COCH ₃ (15 g.); (CH ₂) ₄ C(CH ₃)CO ₂ H (8 g.)	58
C₇H₁₃OCl			
<i>t</i> -C ₄ H ₉ (CH ₂) ₂ COCl (126 g., 0.85 mole)	<i>t</i> -C ₄ H ₉ MgCl (3.3 moles)	<i>t</i> -C ₄ H ₉ (CH ₂) ₃ OH (13.5%); <i>t</i> -C ₄ H ₉ [(<i>t</i> -C ₄ H ₉ (CH ₂) ₂)]CHOH (67.0%)	90
CH ₃ (C ₂ H ₅) ₂ CCOCl (37.1 g.)	CH ₃ MgBr (excess)	CH ₃ (C ₂ H ₅) ₂ CCOCH ₃ (15.3 g., 48%)	59
CH ₃ (<i>t</i> -C ₄ H ₉)CHCOCl	C ₂ H ₅ MgBr	CH ₃ (<i>t</i> -C ₄ H ₉)CHCOC ₂ H ₅	13
C₆H₄O₂ClN			
Benzoxazole-2-carboxylic acid chloride (4 g.)	C ₆ H ₅ MgBr	Diphenyl-2-benzoxazolyloctanol (0.3 g.); 2-benzoxazolyloctanol	60
C₆H₄O₂Cl₂			
C ₆ H ₄ -1,2-(COCl) ₂	2,4-Dimethylpyrrol-MgX	3,3-Bis(3,5-dimethyl-2-pyrrol)phthalide	114
C ₆ H ₄ -1,2-(COCl) ₂	C ₆ H ₅ CH(CO ₂ Na)MgCl*	C ₆ H ₄ -1,2-(CO ₂ H) ₂ (71.0%); (C ₆ H ₅ CH ₂ CO) ₂ O (39.4%); C ₆ H ₅ CH ₂ CO ₂ H (58.8%)	97
C₆H₅OCIBr₂			
2,6-Br ₂ -4-CH ₃ C ₆ H ₂ COCl (32 g.)	CH ₃ MgI (9-fold excess)	2,6-Br ₂ -4-CH ₃ C ₆ H ₂ COCH ₃	49

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₅OCl₂			
C ₆ H ₅ CHClCOCl* (34 g.)	C ₆ H ₅ MgBr (170 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ CHC(C ₆ H ₅) ₂ OH (14.5 g.)	6
C ₆ H ₅ CHClCOCl† (15 g.)	C ₆ H ₅ MgBr (75 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ CHCOC ₆ H ₅ (3 g.)	6
C₆H₇OCl			
C ₆ H ₅ CH ₂ COCl (247 g., 1.6 mole)	<i>t</i> -C ₄ H ₉ MgCl (3.14 moles)	C ₆ H ₅ (CH ₂) ₂ OH (9.2%); <i>t</i> -C ₄ H ₉ (C ₆ H ₅ CH ₂)CHOH (14.9%); C ₆ H ₅ CH ₂ CO ₂ CH(<i>t</i> -C ₄ H ₉)CH ₂ C ₆ H ₅ (20.0%)	90
C ₆ H ₅ CH ₂ COCl (0.1 mole)	C ₆ H ₅ CH(CO ₂ Na)MgX† (0.1 mole)	(C ₆ H ₅ CH ₂) ₂ CO (16 g., 77%); C ₆ H ₅ CH ₂ Cl[CH(C ₆ H ₅)CO ₂ H] ₂ OH (4.2 g., 22%)	20
C ₆ H ₅ CH ₂ COCl (10 g.)	2,6-(CH ₃) ₂ -4-CH ₃ OC ₆ H ₂ MgBr (1.32 g. Mg)	C ₆ H ₅ CH ₂ COC ₆ H ₂ -2,6-(CH ₃) ₂ -4-OCH ₃	63
2-CH ₃ C ₆ H ₄ COCl	2,3,5,6-(CH ₃) ₄ C ₆ HMgBr	2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -2-CH ₃	115
4-CH ₃ C ₆ H ₄ COCl	2,3,5,6-(CH ₃) ₄ C ₆ HMgBr	2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -4-CH ₃	115
C₈H₁₁OCl			
1-Cyclohexenylacetyl chloride	CH ₃ MgI	1-Acetonycyclohexene (40-60%)§	57
C₈H₁₅OCl			
CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CHCOCl (110 g., 0.67 mole)	<i>t</i> -C ₄ H ₉ MgCl (2.7 moles)	CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CHCH ₂ OH (21%); <i>t</i> -C ₄ H ₉ [CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CH]CHOH (67%); gas	90

*Gradual (0.5 hour) addition of Et₂O-chloride solution to Grignard solution; 5.5 hours reflux.

†Slow (1.5 hour) addition of Grignard solution to Et₂O-chloride solution.

‡In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

§Yields of 40-60% are reported for a series of reactions investigated.

TABLE IX-II (Continued)

Halide	RMgX	Product(s)	Ref.
C₈H₁₅OCl (<i>cont.</i>)			
C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CHCOCl (162 g., 1 mole)	<i>t</i> -C ₄ H ₉ MgCl (4.25 moles)	C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CHCH ₂ OH (29.6%); <i>t</i> -C ₄ H ₉ [C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CH]CHOH (64.0%)	90
C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CHCOCl (162.5 g., 1 mole)	<i>t</i> -C ₅ H ₁₁ MgCl (2.56 moles)	C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CHCH ₂ OH (74.5%); <i>t</i> -C ₅ H ₁₁ [C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CH]CHOH (15.7%)	90
(C ₂ H ₅) ₃ CCOCl (157 g.)	CH ₃ MgBr (2 moles)	CH ₄ (<i>ca.</i> 0.5 mole); (C ₂ H ₅) ₃ CCOCH ₃ (45.6 g., 34%); [(C ₂ H ₅) ₃ CCO] ₂ CH ₂ (39.9 g., 32%)	62
(C ₂ H ₅) ₃ CCOCl (0.3 mole)	<i>i</i> -C ₄ H ₉ MgBr (1.0 mole)	(C ₂ H ₅) ₃ CCH ₂ OH (16 g., 40%); (C ₂ H ₅) ₃ CCO- <i>i</i> -C ₄ H ₉ (24.4 g., 43%)	59
(C ₂ H ₅) ₃ CCOCl (144 g., 0.88 mole)	<i>t</i> -C ₄ H ₉ MgCl (2 moles)	(C ₂ H ₅) ₃ CCH ₂ OH (89.5%)	90
C₉H₇OCl			
C ₆ H ₅ CH=CHCOCl	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH=C(C ₆ H ₅)O ₂ CCH=CHC ₆ H ₅ (C ₆ H ₅) ₂ CHCH=CClO ₂ CCH=CHC ₆ H ₅	61
C ₆ H ₅ CH=CHCOCl (0.1 mole)	C ₆ H ₅ CH(CO ₂ Na)MgX* (0.2 mole)	C ₆ H ₅ CH=CHCOCH ₂ C ₆ H ₅ ; C ₆ H ₅ CH ₂ COCH(C ₆ H ₅)CH(C ₆ H ₅)CO ₂ H	20
C₉H₇O₃Cl			
2-CH ₃ CO ₂ C ₆ H ₄ COCl	Indolyl-MgX	3-Salicyloylindole	116
2-CH ₃ CO ₂ C ₆ H ₄ COCl	2-Methylindolyl-MgBr (1 equiv.)	2-Methyl-3-acetylindole; 2-HOC ₆ H ₄ CO ₂ H; 2-(α -methyl- β -indolyl)phenyl α -methyl- β -indolyl ketone hydrobromide; 1,3-o- phenylene-2-methyl-4-(1 <i>H</i>)-quinolone hydrobromide	64

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₇O₂Cl (<i>cont.</i>)			
2-CH ₃ CO ₂ C ₆ H ₄ COCl	2-Methylindolyl-MgBr (2 equiv.)	2-Methyl-3-acetylindole; 2-methyl-3-salicyloylindole; unidentified dark-red product.	64
2-CH ₃ CO ₂ C ₆ H ₄ COCl	3-Methylindolyl-MgX	N-Salicyloylskatole	116
C₉H₈O₂ClN			
C ₆ H ₅ CONHCH ₂ COCl	C ₂ H ₅ MgBr	C ₆ H ₅ CONHCH ₂ C(C ₂ H ₅) ₂ OH (46%)	65
C₉H₉OCl			
C ₆ H ₅ CH ₂ CH ₂ COCl (0.1 mole)	C ₆ H ₅ CH(CO ₂ Na)MgX* (0.2 mole)	C ₆ H ₅ CH ₂ CH ₂ COCH ₂ C ₆ H ₅ (17 g., 76%); C ₆ H ₅ CH ₂ CH ₂ C[CH(C ₆ H ₅)CO ₂ H] ₂ OH (6.2 g., 15%)	20
C₉H₁₃OCl			
2-Methyl-1-cyclohexenylacetyl chloride	CH ₃ MgI	1-Acetonyl-2-methylcyclohexene (40-60%) [†]	57
3-Methyl-1-cyclohexenylacetyl chloride	CH ₃ MgI	1-Acetonyl-3-methylcyclohexene (40-60%) [†]	57
C₉H₁₅OCl			
3-Methylcyclohexylacetyl chloride	CH ₃ MgI	1-Acetonyl-3-methylcyclohexane (40-60%) [†]	57
4-Methylcyclohexylacetyl chloride	CH ₃ MgI	1-Acetonyl-4-methylcyclohexane (40-60%) [†]	57

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

[†]Yields of 40-60% are reported for a series of reactions investigated.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₆OCIN			
Cinchoninyl chloride (8 g. hydrochloride)	Pyrryl-Mgl (5.2 g. pyrrole)	2-Pyrryl 4-quinolyl ketone	67
C₁₀H₉O₂Cl			
4-CH ₃ OC ₆ H ₄ CH=CHCOCl	C ₂ H ₅ O ₂ CCH ₂ Br + Mg	4-CH ₃ OC ₆ H ₄ CH=CHCOCH(COCH ₃)- CO ₂ C ₂ H ₅ ; 4-CH ₃ OC ₆ H ₄ CH=CHCO ₂ - C ₂ H ₅ ; yellow comp ^d , m.p. 176-177°	69
C₁₀H₁₃OCIBr			
2,4,6-(CH ₃) ₃ -3-BrC ₆ HCOC ₂ H ₅ (13.0 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂ MgCl (8.4 g. C ₁₀ H ₁₃ Cl)	2,4,6-(CH ₃) ₃ -3-BrC ₆ HCOCH ₂ C ₆ H ₅ - 2,4,6-(CH ₃) ₃ (8.0 g., 45%)	117
C₁₀H₁₁OCl			
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCl	CH ₃ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₃ (87%); [2,4,6-(CH ₃) ₃ C ₆ H ₂ CO—] ₂ (1%)*	66
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCl (10.95 g.)	CH ₃ MgI (23.7 g. CH ₃ I)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₃ (35%); [2,4,6-(CH ₃) ₃ C ₆ H ₂ CO—] ₂ (39%)*	68
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCl	CH ₃ MgI	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₃ (25%); [2,4,6-(CH ₃) ₃ C ₆ H ₂ CO—] ₂ (50%)*	66
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCl	CH ₃ MgI	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₃ (88%) [†]	68
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCl	CH ₃ MgI	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₃ (83%) [†]	66
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCl (72 g.)	2-CH ₃ OC ₆ H ₄ MgBr (85 g. C ₇ H ₇ BrO)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC ₆ H ₄ -2-OCH ₃ (30 g.)	70
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCl (59 g.)	4-CH ₃ OC ₆ H ₄ MgBr (72 g. C ₇ H ₇ BrO)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC ₆ H ₄ -4-OCH ₃ (28 g.)	118
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCl (173 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (280 g. C ₉ H ₁₁ Br)	[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ CO (149 g.)	71

*Addition of Grignard solution to Et₂O-chloride solution.†Addition of Et₂O-chloride solution to Grignard solution.

TABLE IX-II (Continued).

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₁OCl (<i>cont.</i>)			
2,4,6-(CH ₃) ₃ C ₆ H ₂ COCl (24 g.)	4-C ₆ H ₅ C ₆ H ₄ MgI (40 g. C ₁₂ H ₉ I)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC ₆ H ₄ -4-C ₆ H ₅ (32 g., 80%)	72
C₁₀H₁₁O₄Cl			
3,4,5-(CH ₃ O) ₃ C ₆ H ₂ COCl (29.0 g.)	2,3,5,6-(CH ₃) ₄ C ₆ HMgBr (27.7 g. C ₁₀ H ₁₃ Br)	3,4,5-(CH ₃ O) ₃ C ₆ H ₂ COC ₆ H-2,3,5,6-(CH ₃) ₄ (6.8 g., 16%)	118
C₁₀H₁₅OCl			
?-Methyl-?- <i>n</i> -butyl-1-cyclohexylacetyl chloride	CH ₃ MgI	1-Acetonyl-?-methyl-?- <i>n</i> -butyl-cyclohexene (40-60%)*	57
C₁₀H₁₆O₂Cl₂			
[—(CH ₂) ₄ COCl] ₂ (0.13 mole)	<i>n</i> -C ₆ H ₁₃ MgBr (0.11 mole)	<i>n</i> -C ₆ H ₁₃ CO(CH ₂) ₈ CO ₂ H (28%); diketone (1 g.)	73
[—(CH ₂) ₄ COCl] ₂ (31 g.)	<i>i</i> -C ₆ H ₁₃ MgBr (0.11 mole)	<i>i</i> -C ₆ H ₁₃ CO(CH ₂) ₈ CO ₂ H (7.4 g., 24%)	73
[—(CH ₂) ₄ COCl] ₂	C ₆ H ₅ CH(CO ₂ Na)MgCl [†] (2 equiv.)	[—(CH ₂) ₄ CO ₂ H] ₂ (87.3%); (C ₆ H ₅ CH ₂ CO) ₂ O (15.8%); C ₆ H ₅ CH ₂ CO ₂ H (60.2%)	97
[—(CH ₂) ₄ COCl] ₂	<i>n</i> -C ₈ H ₁₇ MgBr	<i>n</i> -C ₈ H ₁₇ CO(CH ₂) ₈ CO ₂ H (12%)	73
[—(CH ₂) ₄ COCl] ₂ (31 g.)	<i>i</i> -C ₈ H ₁₇ MgBr	<i>i</i> -C ₈ H ₁₇ CO(CH ₂) ₈ CO ₂ H (3.8 g., 11%)	73
C₁₁H₇OCl			
1-C ₁₀ H ₇ COCl (18.5 g.)	1-C ₁₀ H ₇ MgBr (20.0 g. C ₁₀ H ₇ Br)	(1-C ₁₀ H ₇) ₂ CO	74
1-C ₁₀ H ₇ COCl (17 g.)	1-C ₁₀ H ₇ MgBr (60 g. C ₁₀ H ₇ Br)	(1-C ₁₀ H ₇) ₃ COH (5-14 g.)	74

*Yields of 40-60% are reported for a series of reactions investigated.

[†]In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product (s)</u>	<u>Ref.</u>
C₁₁H₇OCl (cont.)			
1-C ₁₀ H ₇ COCl (15.5 g.)	7-Methyl-4-indanyl-MgBr (10.0 g. C ₁₀ H ₁₁ Br)	7-Methyl-4-indanyl 1-naphthyl ketone	119
1-C ₁₀ H ₇ COCl (15 g.)	7-Isopropyl-4-indanyl-MgBr (10 g. C ₁₂ H ₁₅ Br)	(1-C ₁₀ H ₇ CO) ₂ O (3 g.); 1-isopropylindan (2 g.); 7-isopropyl-4-indanyl 1-naphthyl ketone (7.3 g., 55.5%)	75
2-C ₁₀ H ₇ COCl (17 g.)	1-C ₁₀ H ₇ MgBr (60 g. C ₁₀ H ₇ Br)	2-C ₁₀ H ₇ (1-C ₁₀ H ₇) ₂ COH (20 g., crude)	76
2-C ₁₀ H ₇ COCl	2-C ₁₀ H ₇ MgBr	(2-C ₁₀ H ₇) ₃ CH; (2-C ₁₀ H ₇) ₃ COH	77
2-C ₁₀ H ₇ COCl (15.5 g.)	7-Methyl-4-indanyl-MgBr (10.0 g. C ₁₀ H ₁₁ Br)	7-Methyl-4-indanyl 2-naphthyl ketone (6.1 g., 45%)	119
C₁₁H₈O₂Cl			
6-Methoxy-4-quinolinecarboxylic acid chloride (8.8 g. hydrochloride)	Pyrryl-MgI (5.0 g. pyrrole)	2-Pyrryl 6-methoxy-4-quinoliny ketone	67
6-Methoxy-4-quinolinecarboxylic acid chloride (7 g. hydrochloride)	3,5-Dimethylpyrryl-MgI (6 g. dimethylpyrrole)	3,5-Dimethyl-2-pyrryl 6-methoxy-4-quinoliny ketone	67
C₁₁H₁₃OCl			
2,3,5,6-(CH ₃) ₄ C ₆ HCOC1 (30.0 g.)	2-CH ₃ OC ₆ H ₄ MgBr (26.0 g. C ₇ H ₇ BrO)	2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -2-OCH ₃ (10.4 g.); 2,3,5,6-(CH ₃) ₄ C ₆ HCO ₂ H (7.0 g.)	118
2,3,5,6-(CH ₃) ₄ C ₆ HCOC1 (0.02 mole)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (0.02 mole C ₉ H ₁₁ Br)	2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₂ -2,4,6-(CH ₃) ₃	81
2,3,5,6-(CH ₃) ₄ C ₆ HCOC1 (0.02 mole)	2,6-(CH ₃) ₂ -4- <i>i</i> -C ₄ H ₉ C ₆ H ₂ MgBr (1 equiv.)	2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₂ -2,6-(CH ₃) ₂ -4- <i>i</i> -C ₄ H ₉	81
2,3,5,6-(CH ₃) ₄ C ₆ HCOC1 (8.4 g.)	2-C ₆ H ₅ CH ₂ C ₆ H ₄ MgBr (13.6 g. C ₁₃ H ₁₁ Br)	2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -2-CH ₂ C ₆ H ₅ (6.9 g., 49%)	124

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₇OCl			
Camphane-2-carboxylic acid chloride	<i>i</i> -C ₃ H ₇ MgX + FeCl ₃ (1%)	Isopropyl bornyl ketone (40%)	82
Camphane-2-carboxylic acid chloride	<i>n</i> -C ₄ H ₉ MgX + FeCl ₃ (1%)	<i>n</i> -Butyl bornyl ketone (66%)	82
Camphane-2-carboxylic acid chloride	<i>t</i> -C ₄ H ₉ MgX + FeCl ₃ (1%)	<i>t</i> -Butyl bornyl ketone (36%)	82
Camphane-2-carboxylic acid chloride	C ₆ H ₅ MgX + FeCl ₃ (1%)	Phenyl bornyl ketone (80%)	82
Camphane-2-carboxylic acid chloride	1-C ₁₀ H ₇ MgBr + FeCl ₃ (1%)	1-Naphthyl bornyl ketone (70%)	82
Camphane-2-carboxylic acid chloride	Bornyl-MgCl + FeCl ₃ (1%)	Dibornyl ketone	82
C₁₁H₁₃OCl			
CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCOCl (271 g.)	CH ₃ MgBr (4 moles)	CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCOCH ₃ (223.5 g., 91%)	78
CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCOCl (70.2 g.)	C ₂ H ₅ MgBr (87.2 g. C ₂ H ₅ Br)	CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCOC ₂ H ₅ (53.6 g., 79%)	78
CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCOCl (218 g.)	<i>i</i> -C ₃ H ₇ MgBr (2 moles C ₃ H ₇ Br)	CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCO- <i>i</i> -C ₃ H ₇ (130.5 g., 58%)	78
C₁₂H₉OCl			
2-CH ₃ C ₁₀ H ₆ -1-COCl (50 g.)	CH ₃ MgI (110 g. CH ₃ I)	1-CH ₃ COC ₁₀ H ₆ -2-CH ₃ (40 g., 89%)	79
2-CH ₃ C ₁₀ H ₆ -1-COCl (15 g.)	C ₂ H ₅ MgBr	1-C ₂ H ₅ COC ₁₀ H ₆ -2-CH ₃ (13.5 g., 95%)	79
C₁₂H₉O₂Cl			
2-CH ₃ OC ₁₀ H ₆ -1-COCl	C ₂ H ₅ MgBr	1-C ₂ H ₅ COC ₁₀ H ₆ -2-OCH ₃	120

TABLE IX-II (Continued)

Halide	RMgX	Product(s)	Ref.
C₁₂H₁₀O₂Cl			
6-Ethoxy-4-quinolinecarboxylic acid chloride (9.0 g. hydrochloride)	Pyrryl-Mgl (5.2 g. pyrrole)	2-Pyrryl 6-ethoxy-4-quinolinyll ketone	67
C₁₂H₂₁O₃Cl			
H ₅ C ₂ O ₂ C(CH ₂) ₈ COCl (0.1 mole)	<i>i</i> -C ₄ H ₉ MgBr (<i>ca.</i> 0.1 mole)	<i>i</i> -C ₄ H ₉ CO(CH ₂) ₈ CO ₂ C ₂ H ₅ (43-47%)	73
C₁₂H₂₃OCl			
<i>n</i> -C ₁₁ H ₂₃ COCl (0.75 mole)	<i>t</i> -C ₄ H ₉ MgCl (2.40 mole)	<i>n</i> -C ₁₂ H ₂₅ OH (13.7%); <i>t</i> -C ₄ H ₉ (<i>n</i> -C ₁₁ H ₂₃)CHOH (67.0%)	90
<i>n</i> -C ₁₁ H ₂₃ COCl (0.50 mole)	<i>t</i> -C ₅ H ₁₁ MgCl (1.22 mole)	<i>n</i> -C ₁₂ H ₂₅ OH (54.8%); <i>t</i> -C ₅ H ₁₁ (<i>n</i> -C ₁₁ H ₂₃)CHOH (17.7%)	90
(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOCl* (1 mole)	CH ₃ MgBr (2.4 moles)	(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOCH ₃ (142.6 g., 72%); CH ₄	80
(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOCl† (1 mole)	CH ₃ MgBr (2 moles)	(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOCH ₃ (65 g., 33%); (<i>t</i> -C ₄ H ₉ CH ₂ CO) ₂ CH ₂ (106 g., 56%)	80
(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOCl* (0.5 mole)	C ₂ H ₅ MgBr (1.24 mole)	(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOC ₂ H ₅ (81 g., 76%); (<i>t</i> -C ₄ H ₉ CH ₂ CO) ₂ CHCH ₃ (10 g., 10%)	80
(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOCl (152 g., 0.7 mole)	<i>t</i> -C ₄ H ₉ MgCl (2.3 mole)	(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCH ₂ OH (60%); <i>t</i> -C ₄ H ₉ [(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CH]CHOH (17%)	90
(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOCl† (0.5 mole)	C ₆ H ₅ MgBr (0.48 mole)	(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOC ₆ H ₅ (110 g.)	80
(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOCl (0.25 mole)	2-CH ₃ C ₆ H ₄ MgBr (0.21 mole)	(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOC ₆ H ₄ -2-CH ₃ (33 g., crude)	80
(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOCl (0.125 mole)	4-CH ₃ C ₆ H ₄ MgBr (0.112 mole)	(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOC ₆ H ₄ -4-CH ₃ (26.3 g., 85%)	80

* Addition of chloride to Grignard reagent solution.

† Addition of Grignard reagent solution to chloride.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₂₃OCl (<i>cont.</i>)			
CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCOCl (218 g., 1 mole)	<i>t</i> -C ₄ H ₉ MgCl (3 moles)	CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCH ₂ OH (19.7%); CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCHO (62.5%)	90
CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCOCl (0.435 mole)	<i>t</i> -C ₅ H ₁₁ MgCl (1.19 mole)	CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCH ₂ OH (19%); CH ₃ (<i>t</i> -C ₄ H ₉)(<i>t</i> -C ₄ H ₉ CH ₂)CCHO (78%)	90
C₁₃H₁₀OClN			
(C ₆ H ₅) ₂ NCOCl	RMgX*	RCON(C ₆ H ₅) ₂	121
C₁₃H₁₁OCl			
2-C ₂ H ₅ C ₁₀ H ₆ -1-COCl (12.0 g.)	C ₂ H ₅ MgBr (16.4 g. C ₂ H ₅ Br)	1-C ₂ H ₅ COC ₁₀ H ₆ -2-C ₂ H ₅ (86%)	120
C₁₃H₁₇OCl			
2,4,6-(C ₂ H ₅) ₃ C ₆ H ₂ COCl (28.3 g.)	CH ₃ MgI (200 ml., 1.35 M)	2,4,6-(C ₂ H ₅) ₃ C ₆ H ₂ COCH ₃ (9.8 g., 38.4%); [2,4,6-(C ₂ H ₅) ₃ C ₆ H ₂ CO —] ₂ (7.75 g., 32.5%)	68
C₁₄H₉OCl			
Fluorene-4-carbonyl chloride (16.6 g.)	C ₆ H ₅ MgBr (6.8 ml. C ₆ H ₅ Br)	Fluorene-4-carboxylic acid (4.84 g.); 4-benzoylfluorene (9.81 g.)	122
C₁₄H₁₀OCl₂			
(C ₆ H ₅) ₂ CClCOCl (40 g.)	C ₆ H ₅ MgBr (144 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)OH (58%); (C ₆ H ₅ —) ₂ (13.3 g.) [†]	83
(C ₆ H ₅) ₂ CClCOCl (40 g.)	C ₆ H ₅ MgBr (85 g. C ₆ H ₅ Br)	C ₃₄ H ₂₆ O ₂ , m.p. 256.5–257.5° (4.5 g.); (C ₆ H ₅ —) ₂ (12.8 g.); resin (37 g.) [‡]	83

*RMgX = C₂H₅MgI, *n*-C₃H₇MgBr, C₆H₅MgBr.[†]Gradual addition of Et₂O-chloride solution to Grignard reagent solution.[‡]Gradual addition of Grignard reagent solution to Et₂O-chloride solution.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₀OCl₂ (<i>cont.</i>)			
(C ₆ H ₅) ₂ CClCOCl (13 g.)	C ₆ H ₅ MgI (35 g. C ₆ H ₅ I)	Resin.*	83
(C ₆ H ₅) ₂ CClCOCl (13 g.)	C ₆ H ₅ MgI (60 g. C ₆ H ₅ I)	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)OH (8.1 g., crude) [†]	83
C₁₄H₁₁OCl			
(C ₆ H ₅) ₂ CHCOCl (1.3 mole)	<i>t</i> -C ₄ H ₉ MgCl (3.4 moles)	(C ₆ H ₅) ₂ CHCH ₂ OH (67.5%)	90
C₁₄H₂₇OCl			
(<i>n</i> -C ₄ H ₉) ₃ CCOCl (119 g., 0.48 mole)	<i>t</i> -C ₄ H ₉ MgCl (1.5 mole)	(<i>n</i> -C ₄ H ₉) ₃ CCH ₂ OH (88.5%)	90
C₁₅H₁₂O₂ClN			
C ₆ H ₅ CONHCH(C ₆ H ₅)COCl	C ₂ H ₅ MgBr	C ₆ H ₅ CONHCH(C ₆ H ₅)C(C ₂ H ₅) ₂ OH (37%)	65
C₁₆H₂₃OCl			
2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ COCl (26.6 g.)	2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ MgBr (30.0 g. C ₁₅ H ₂₃ Br)	[2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂] ₂ CO	91
C₁₇H₁₇OCl			
2,4,6-(CH ₃) ₃ C ₆ H ₂ (C ₆ H ₅)CHCOCl (10 g.)	CH ₃ MgI (7.25 g. CH ₃ I)	2,4,6-(CH ₃) ₃ C ₆ H ₂ (C ₆ H ₅)CHCO ₂ H (1.1 g.); 2,4,6-(CH ₃) ₃ C ₆ H ₂ (C ₆ H ₅)CHCOCH ₃ (< 50%); 2,4,6-(CH ₃) ₃ C ₆ H ₂ (C ₆ H ₅)C=C(CH ₃) ₂	84
2,4,6-(CH ₃) ₃ C ₆ H ₂ (C ₆ H ₅)CHCOCl (0.08 mole)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (0.08 mole)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH(C ₆ H ₅)C ₆ H ₂ -2,4,6-(CH ₃) ₃ (10 g.); 2,4,6-(CH ₃) ₃ C ₆ H ₂ (C ₆ H ₅)-CHCO ₂ H (6 g.)	89

*Gradual addition of Et₂O-chloride solution to Grignard reagent solution.[†]Gradual addition of Grignard reagent solution to Et₂O-chloride solution.

TABLE IX-II (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₂₅OCl			
2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ CH ₂ COCl	2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ MgBr	2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ COCH ₂ C ₆ H ₂ -2,4,6-(<i>i</i> -C ₃ H ₇) ₃	91
C₁₈H₁₄O₂Cl₂			
α -Truxillyl chloride*	C ₆ H ₅ MgBr	No crystalline product	92
C₂₀H₁₅OCl			
(C ₆ H ₅) ₃ CCOCl (7 g.)	C ₂ H ₅ MgI (20 g. C ₂ H ₅ I)	(C ₆ H ₅) ₃ CCOC ₂ H ₅ (2.5 g.); C ₂ H ₄	85
(C ₆ H ₅) ₃ CCOCl (7 g.)	C ₆ H ₅ MgBr (20 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ CC(C ₆ H ₅) ₂ OH (4 g.)	85
(C ₆ H ₅) ₃ CCOCl† (17 g.)	C ₆ H ₅ MgI (40 g. C ₆ H ₅ I)	CO (86.4%); [(C ₆ H ₅) ₃ C —] ₂ (4.8 g.); (C ₆ H ₅) ₃ CC(C ₆ H ₅) ₂ OH (trace)	85
(C ₆ H ₅) ₃ CCOCl‡ (15 g.)	C ₆ H ₅ MgI (21 g. C ₆ H ₅ I)	[(C ₆ H ₅) ₃ C] ₂ O ₂ (0.7 g.); CO; (C ₆ H ₅) ₃ C \dot{O} H (4.4 g.); (C ₆ H ₅) ₃ CH (3.5 g.)	85
C₂₀H₂₃OCl			
[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ CHCOCl (22.7 g.)	C ₆ H ₅ MgBr (7.85 g. C ₆ H ₅ Br)	[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ CHCO ₂ C ₂ H ₅ ; [2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ CHCOC ₆ H ₅ ; tar	84
C₂₄H₃₅O₃Cl			
3-Acetoxy-5-bisnorcholenic acid chloride (from 5 g. acid)	CH ₃ MgBr (5 g. Mg)	3-Hydroxy-5-ternorcholenyldimethyl- carbinol (4.6 g.)	86
C₂₈H₄₅OCl			
5-Cholestene-3-carbonyl chloride (from 2.84 g. acid)	CH ₃ MgI (0.02 mole CH ₃ I)	α -(3-Cholesteryl)ethanol	93

*2,4-Diphenylcyclobutane-1,3-dicarbonyl chloride.

†Addition of powdered chloride to Grignard solution at room temperature; two days standing.

‡Reaction in boiling Et₂O.

REFERENCES FOR TABLE IX-II.

- (1) Grignard, *Compt. rend.*, 136, 815-7 (1903); *Chem. Zentr.*, 1903,1, 1077.
- (2) Sachs and Loevy, *Ber.*, 36, 1588-90 (1903).
- (3) Kohler and Blanchard, *J. Am. Chem. Soc.*, 57, 367-71 (1935).
- (4) Huston, Jackson, and Spero, *J. Am. Chem. Soc.*, 63, 1459-60 (1941).
- (5) Henry, *Compt. rend.*, 145, 21-5 (1907); *Chem. Zentr.*, 1907,11, 889.
- (6) Boyle, McKenzie, and Mitchell, *Ber.*, 70B, 2153-60 (1937).
- (7) Mingoia, *Gazz. chim. ital.*, 61, 646-50 (1931); *Chem. Abstr.*, 26, 1279 (1932).
- (8) Tissier and Grignard, *Compt. rend.*, 132, 336-8 (1901); *Chem. Zentr.*, 1901,1, 930; *J. Chem. Soc.*, 80,1, 316 (1901).
- (9) Oddo, *Ber.*, 43, 1015-21 (1910).
- (10) Whitmore, Popkin, Whitaker, Mattil, and Zech, *J. Am. Chem. Soc.*, 60, 2458-62 (1938).
- (11) Whitmore, *Rec. trav. chim.*, 57, 562-8 (1938).
- (12) Whitmore and Badertscher, *J. Am. Chem. Soc.*, 55, 1559-67 (1933).
- (13) Whitmore and Block, *J. Am. Chem. Soc.*, 64, 1619-21 (1942).
- (14) Whitmore and Wheeler, *J. Am. Chem. Soc.*, 60, 2899-900 (1938).
- (15) Huston and Guile, *J. Am. Chem. Soc.*, 61, 69-71 (1939).
- (16) Tissier and Grignard, *Compt. rend.*, 132, 1182-4 (1901); *Chem. Zentr.*, 1901,1, 1357.
- (17) Gilman, Fothergill, and Parker, *Rec. trav. chim.*, 48, 748-51 (1929).
- (18) Oddo and Acuto, *Gazz. chim. ital.*, 65, 1029-36 (1935); *Chem. Abstr.*, 30, 4857 (1936).
- (19) Whitmore and Sloat, *J. Am. Chem. Soc.*, 64, 2968-70 (1942).
- (20) Ivanoff and Nicoloff, *Bull. soc. chim.*, [4], 51, 1331-7 (1932).
- (21) Campbell, Anderson, and Gilmore, *J. Chem. Soc.*, 1940, 819-21.
- (22) Savard and Hösögüt, *Rev. faculté sci. univ. Istanbul*, [N.S.], 3, 164-73 (1938); *Chem. Abstr.*, 32, 5795 (1938).
- (23) Clément, *Ann. chim.*, [11], 13, 243-316 (1940).
- (24) Miller and Bachmann, *J. Am. Chem. Soc.*, 57, 766-71 (1935).
- (25) Schmidlin and Hodgson, *Ber.*, 41, 430-7 (1908).
- (26) Lapkin and Lyubimova, *Zhur. Obschei Khim.*, 19, 707-16 (1949); *Chem. Abstr.*, 44, 1058 (1950); *J. Gen. Chem. (U.S.S.R.)*, 19, 677-88 (1949); *Chem. Abstr.*, 44, 6391 (1950).
- (27) Austin and Johnson, *J. Am. Chem. Soc.*, 54, 647-60 (1932).
- (28) Bachmann and Cockerill, *J. Am. Chem. Soc.*, 55, 2932-4 (1933).
- (29) Hess, *Ber.*, 46, 3113-25 (1913).
- (30) Gilman and Franz, *Rec. trav. chim.*, 51, 991-5 (1932).
- (31) Petrov and Roslova, *J. Gen. Chem. (U.S.S.R.)*, 10, 993-6 (1940); *Chem. Abstr.*, 35, 2467 (1941).
- (32) Houben, *Ber.*, 36, 3087-9 (1903).
- (33) Gilman, Kirby, Fothergill, and Harris, *Proc. Iowa Acad. Sci.*, 34, 221-2 (1927); *Chem. Abstr.*, 22, 4504 (1922).
- (34) Blicke, Warzynski, Faust, and Gearien, *J. Am. Chem. Soc.*, 66, 1675-7 (1944).
- (35) Bachmann, *J. Am. Chem. Soc.*, 56, 1363-7 (1934).
- (36) Hurd and Kelso, *J. Am. Chem. Soc.*, 62, 2184-7 (1940).
- (37) Grignard, *Compt. rend.*, 136, 1200-1 (1903); *Chem. Zentr.*, 1903,11, 22.
- (38) Grignard, *Bull. soc. chim.*, [3], 29, 948-53 (1903).
- (39) Greenwood, Whitmore, and Crooks, *J. Am. Chem. Soc.*, 60, 2028-30 (1938).
- (40) Vavon and Décombe, *Bull. soc. chim.*, [5], 11, 363-5 (1944).
- (41) Stehman, Cook, and Whitmore, *J. Am. Chem. Soc.*, 71, 1509-10 (1949).
- (42) Jacobs, Cramer, and Weiss, *J. Am. Chem. Soc.*, 62, 1849-54 (1940).
- (43) Whitmore and Forster, *J. Am. Chem. Soc.*, 64, 2966-8 (1942).

- (44) Whitmore, Popkin, Whitaker, Mattil, and Zech, *J. Am. Chem. Soc.*, 60, 2462-4 (1938).
- (45) Whitmore, Meyer, Pedlow, and Popkin, *J. Am. Chem. Soc.*, 60, 2788-9 (1938).
- (46) Whitmore, Whitaker, Mattil, and Popkin, *J. Am. Chem. Soc.*, 60, 2790-2 (1938).
- (47) Whitmore and Heyd, *J. Am. Chem. Soc.*, 60, 2030-1 (1938).
- (48) Helferich and Malkomes, *Ber.*, 55B, 702-8 (1922).
- (49) Fuson, Van Campen, and Wolf, *J. Am. Chem. Soc.*, 60, 2269-72 (1938).
- (50) Ross and Fuson, *J. Am. Chem. Soc.*, 59, 1508-10 (1937).
- (51) Cobb, *Am. Chem. J.*, 35, 486-508 (1906).
- (52) Gilman and Mayhue, *Rec. trav. chim.*, 51, 47-50 (1932).
- (53) Acree, *Ber.*, 37, 625-8 (1904).
- (54) Clément, *Compt. rend.*, 202, 425-7 (1936); *Chem. Abstr.*, 30, 2932 (1936).
- (55) Koelsch, *J. Am. Chem. Soc.*, 54, 2045-8 (1932).
- (56) Koelsch, *J. Am. Chem. Soc.*, 54, 3384-9 (1932).
- (57) Darzens and Rost, *Compt. rend.*, 153, 772-5 (1911); *Chem. Zentr.*, 1911, 11, 1860.
- (58) Meerwein, *Ann.*, 417, 255-77 (1918).
- (59) Whitmore and Lewis, *J. Am. Chem. Soc.*, 64, 2964-6 (1942).
- (60) Skraup and Moser, *Ber.*, 55B, 1080-101 (1922).
- (61) Kohler and Heritage, *Am. Chem. J.*, 33, 21-35 (1905).
- (62) Whitmore and Lewis, *J. Am. Chem. Soc.*, 64, 1618-9 (1942).
- (63) Fuson and Hoch, *J. Am. Chem. Soc.*, 71, 1585-6 (1949).
- (64) Toffoli, *Gazz. chim. ital.*, 64, 364-71 (1934); *Chem. Abstr.*, 28, 6437 (1934).
- (65) Thomas and Bettzieche, *Z. physiol. Chem.*, 140, 279-98 (1924); *Chem. Abstr.*, 19, 636 (1925).
- (66) Kharasch, Morrison, and Urry, *J. Am. Chem. Soc.*, 66, 368-71 (1944).
- (67) Karrer, *Ber.*, 50, 1499-508 (1917).
- (68) Fuson and Corse, *J. Am. Chem. Soc.*, 60, 2063-6 (1938).
- (69) Macierewicz, *Roczniki Chem.*, 22, 93-5 (1948); *Chem. Abstr.*, 43, 2973 (1949).
- (70) Fuson and Speck, *J. Am. Chem. Soc.*, 64, 2446-8 (1942).
- (71) Kohler and Baltzly, *J. Am. Chem. Soc.*, 54, 4015-26 (1932).
- (72) Fuson, Armstrong, and Speck, *J. Org. Chem.*, 7, 297-302 (1942).
- (73) Fordyce and Johnson, *J. Am. Chem. Soc.*, 55, 3368-72 (1933).
- (74) Schmidlin and Massini, *Ber.*, 42, 2377-92 (1909).
- (75) Bruce and Todd, *J. Am. Chem. Soc.*, 61, 157-61 (1939).
- (76) Schmidlin and Massini, *Ber.*, 42, 2392-404 (1909).
- (77) Schmidlin and Huber, *Ber.*, 43, 2824-37 (1910).
- (78) Whitmore and Randall, *J. Am. Chem. Soc.*, 64, 1242-6 (1942).
- (79) Adams and Binder, *J. Am. Chem. Soc.*, 63, 2773-6 (1941).
- (80) Whitmore and Lester, *J. Am. Chem. Soc.*, 64, 1247-51 (1942).
- (81) Fuson and Tull, *J. Am. Chem. Soc.*, 71, 2542-6 (1949).
- (82) Quesnel and Tatibouet, *Bull. soc. chim.*, [5], 14, 1079-80 (1947).
- (83) McKenzie and Boyle, *J. Chem. Soc.*, 119, 1131-40 (1921).
- (84) Fuson, Armstrong, Chadwick, Kneisley, Rowland, Shenk, and Soper, *J. Am. Chem. Soc.*, 67, 386-93 (1945).
- (85) Schmidlin, *Ber.*, 43, 1137-44 (1910).
- (86) Julian, Cole, Meyer, and Herness, *J. Am. Chem. Soc.*, 67, 1375-81 (1945).
- (87) Buu-Hoï and Nguyen-Hoân, *Rec. trav. chim.*, 68, 5-33 (1949).
- (88) Grunert, Nichol, and Sandin, *J. Am. Chem. Soc.*, 69, 2254-6 (1947).
- (89) Fuson, Armstrong, Kneisley, and Shenk, *J. Am. Chem. Soc.*, 66, 1464-6 (1944).
- (90) Whitmore, Whitaker, Mosher, Breivik, Wheeler, Miner, Sutherland, Wagner, Clapper, Lewis, Lux, and Popkin, *J. Am. Chem. Soc.*, 63, 643-54 (1941).

- (91) Fuson, Chadwick, and Ward, *J. Am. Chem. Soc.*, 68, 389-93 (1946).
(92) Adler, *Sitzber. Abhandl. naturforsch. Ges. Rostock*, 7, 3-20 (1938-9); *Chem. Abstr.*, 37, 345 (1934).
(93) Baker and Squire, *J. Am. Chem. Soc.*, 70, 1487-90 (1948).
(94) Fischer and Orth, *Ann.*, 502, 237-64 (1933).
(95) Ghigi and Scaramelli, *Boll. sci. facoltà chim. ind. univ. Bologna*, 4, 83-5 (1943); *Chem. Abstr.*, 42, 3389 (1948).
(96) Oddo and Mingoa, *Gazz. chim. ital.*, 57, 473-9 (1927); *Chem. Abstr.*, 22, 77 (1928).
(97) Stefanova, *Annuaire univ. Sofia, Faculté phys.-math.*, 40, Livre 2, 147-66 (1943-44); *Chem. Abstr.*, 42, 4156 (1948).
(98) Jacob, *Bull. soc. chim.*, [5], 7, 581-6 (1940).
(99) Fischer, Baumgartner, and Plotz, *Ann.*, 493, 1-19 (1932).
(100) Oddo and Moschini, *Gazz. chim. ital.*, 42, II, 244-56 (1912); *Chem. Abstr.*, 6, 3425 (1912).
(101) Whitmore, Sommer, Gold, and Van Strien, *J. Am. Chem. Soc.*, 69, 1551 (1947).
(102) Kroeger and Nieuwland, *J. Am. Chem. Soc.*, 58, 1861-3 (1936).
(103) Hess and Weltzien, *Ber.*, 54B, 2511-21 (1921).
(104) Ingraffia, *Gazz. chim. ital.*, 63, 584-91 (1933); *Chem. Abstr.*, 28, 1342 (1934).
(105) Fischer and Hussong, *Ann.*, 492, 128-55 (1932).
(106) Rivière, *Ann. chim.*, [12], 1, 157-231 (1946).
(107) Sanna, *Rend. seminario facoltà sci. univ. Cagliari*, 4, 59-61 (1934); *Chem. Abstr.*, 29, 1815 (1935).
(108) Oddo, *Gazz. chim. ital.*, 50, II, 258-68 (1920); *Chem. Abstr.*, 15, 2096 (1921).
(109) Oddo and Albanese, *Gazz. chim. ital.*, 57, 827-35 (1927); *Chem. Abstr.*, 22, 1775 (1928).
(110) Bachman and Micucci, *J. Am. Chem. Soc.*, 70, 2381-4 (1948).
(111) Fuson, Bertetti, and Ross, *J. Am. Chem. Soc.*, 54, 4380-3 (1932).
(112) Hurd, Jones, and Blunck, *J. Am. Chem. Soc.*, 57, 2033-6 (1935).
(113) Mousseron and Granger, *Bull. soc. chim.*, [5], 13, 251-6 (1946).
(114) Ingraffia, *Gazz. chim. ital.*, 64, 289-94 (1934); *Chem. Abstr.*, 28, 5437 (1934).
(115) Fuson, McKusick, and Mills, *J. Org. Chem.*, 11, 60-6 (1946).
(116) Toffoli, *Gazz. chim. ital.*, 65, 459-61 (1935); *Chem. Abstr.*, 30, 455 (1936).
(117) Fuson, Lindsey, and Welldon, *J. Am. Chem. Soc.*, 64, 2888-91 (1942).
(118) Fuson and Gaertner, *J. Org. Chem.*, 13, 496-501 (1948).
(119) Fieser and Seligman, *J. Am. Chem. Soc.*, 57, 942-6 (1935).
(120) Fuson and Chadwick, *J. Org. Chem.*, 13, 484-8 (1948).
(121) Meyer, *J. prakt. Chem.*, [2], 82, 521-38 (1910).
(122) Bachmann and Brockway, *J. Org. Chem.*, 13, 394-9 (1948).
(123) Vavon and Décombe, *Compt. rend.*, 214, 360-2 (1942); *Chem. Abstr.*, 37, 3733 (1943).
(124) Fuson and McKusick, *J. Am. Chem. Soc.*, 65, 60-4 (1943).
(125) Lutz and Smith, *J. Am. Chem. Soc.*, 63, 1148-50 (1941).
(126) Kohler and Tishler, *J. Am. Chem. Soc.*, 57, 217-24 (1935).
(127) Kohler and Potter, *J. Am. Chem. Soc.*, 58, 2166-70 (1936).
(128) Kohler and Potter, *J. Am. Chem. Soc.*, 57, 1316-21 (1935).
(129) Gaertner, *J. Am. Chem. Soc.*, 74, 766-7 (1952).
(130) Chelintzev and Skvortzov, *J. Russ. Phys.-Chem. Soc.*, 47, 170-6 (1915); *Chem. Abstr.*, 9, 1472 (1915).
(131) Gilman and Towle, *Rec. trav. chim.*, 69, 428-32 (1950).
(132) Ford, Thompson, and Marvel, *J. Am. Chem. Soc.*, 57, 2619-23 (1935).
(133) Gaertner, *J. Am. Chem. Soc.*, 73, 3934-7 (1951).

CHAPTER X

Reactions of Grignard Reagents with Nitriles and Other Cyano Compounds

THE "NORMAL" REACTION AND ITS PROBABLE MECHANISM

The reactions of Grignard reagents with nitriles were first investigated by Blaise,¹ who found that in ethereal solution organomagnesium iodides react to form compounds of the general formula $RR'C \equiv NMgI \cdot Et_2O$, which upon acid hydrolysis yield the corresponding ketones ($RR'CO$).

Moureu and Mignonac² have shown that, in some cases at least, the ketimines may be liberated from the Grignard reaction products by sufficiently mild hydrolytic procedure (as with aqueous ammonium chloride at -15°), and isolated as hydrochlorides by treatment of the dried ethereal solutions with dry hydrogen chloride. To this extent the product obtained (whether ketone or ketimine) depends upon the recovery procedure adopted. However, some ketimines are so susceptible to hydrolysis that they are difficult to isolate from aqueous Grignard hydrolysates,* whereas others are so stable that rather vigorous secondary hydrolysis is necessary to obtain the ketones.

By means of competition experiments,[†] Gilman³ has determined that the radical order of reactivity of various benzonitriles toward phenylmagnesium bromide is: $p\text{-ClC}_6\text{H}_4 > \text{C}_6\text{H}_5 > (m\text{-CH}_3\text{C}_6\text{H}_4, p\text{-CH}_3\text{C}_6\text{H}_4) > o\text{-}$

¹ Blaise, *Compt. rend.*, 132, 38 (1901); *J. Chem. Soc.*, 80, 1, 133 (1901); *Chem. Zentr.*, 1901, I, 298; *Compt. rend.*, 133, 1217-8 (1901); *J. Chem. Soc.*, 82, 1, 164 (1902); *Chem. Zentr.*, 1902, I, 299.

² Moureu and Mignonac, *Compt. rend.*, 156, 1801-6 (1913); *Chem. Zentr.*, 1913, II, 497.

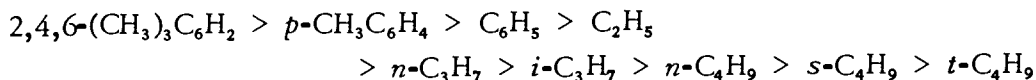
* In such cases, however, the ketimine (or its hydrochloride) may often be isolated by application of the liquid ammonia solvolysis method developed independently by Cornell [*J. Am. Chem. Soc.*, 50, 3311-8 (1928)] and Cloke [Cloke and Van Wyck, *Thesis*, Rensselaer Polytechnic Institute, 1927; Cloke, *J. Am. Chem. Soc.*, 62, 117-9 (1940); Cloke, Baer, Robbins, and Smith, *ibid.*, 67, 2155-8 (1945)].

[†] These experiments were conducted with the aid of the Michler's ketone color test. This test is not reliable in the presence of appreciable quantities of relatively reactive Grignard reagent co-reactants—specifically those more reactive than Michler's ketone itself (see Chapter III, Estimation and Detection of Grignard Reagents). For comparison of the relatively unreactive benzonitriles the test is probably altogether satisfactory.

³ Gilman and Lichtenwalter, *Rec. trav. chim.*, 55, 588-90 (1936).

$\text{CH}_3\text{C}_6\text{H}_4 > p\text{-(CH}_3)_2\text{NC}_6\text{H}_4$. Excepting the slightly displaced *o*-tolunitrile, for which some small "ortho effect" might be expected in reactions of this kind, the order of decreasing reactivity is the order of increasing radical "electronegativity" as assigned by Kharasch *et al.*⁴

In a similar manner Gilman⁵ has determined the relative reactivities of various Grignard reagents toward benzonitrile. Ignoring the atypical allyl and phenylethynyl radicals, the radical order of decreasing reactivity is:



In so far as the members of the series are common, this is the reverse of the order of reactivity toward benzophenone, as determined by Kharasch and Weinhouse.⁶

Swain⁷ has studied the kinetics of the reaction between *n*-butylmagnesium bromide and benzonitrile, and has found the reaction to be homogeneous and second order. The rate constants at 0° and at 25° are, respectively, $5.8 \pm 0.9 \times 10^{-5}$ and $3.7 \pm 0.6 \times 10^{-4}$ l. mole⁻¹ sec.⁻¹, corresponding to an activation energy of 12.0 ± 1.0 kcal.

Concerning the probable mechanism of the reaction Swain says:

"The second-order kinetics of the reaction between *n*-butylmagnesium bromide and benzonitrile eliminates from consideration a mechanism involving a unimolecular or solvolytic ionization of the organometallic reagent to a carbanion as the rate-determining step.

"Formation of a complex between reagent and addend seems to be eliminated as the rate-determining step by the whole series of relative reactivity of different nitriles obtained by Gilman. For example benzonitrile reacts faster with phenylmagnesium bromide than does *p*-tolunitrile, although the latter would be expected to be more nucleophilic and to form a stronger complex from a consideration of inductive effects.

"A rate-determining reaction of a complex with a second molecule of Grignard reagent is eliminated because it would require the kinetics to be second order in the reagent alone and third order over-all.

"Direct reaction of Grignard reagent with nitrile is unlikely, because then we should expect the aliphatic reagents to react faster than phenyl Grignard. Ethylsodium will react with benzene to give phenylsodium and

⁴For a discussion of the relative electronegativities of organic radicals see: Kharasch and Reinmuth, *J. Chem. Education*, 5, 404-18 (1928); 8, 1703-48 (1931); Kharasch, Reinmuth, and Mayo, *ibid.*, 11, 82-96 (1934); 13, 7-19 (1936). The electronegativity of the *p*-dimethylaminophenyl radical cannot be evaluated directly by the Kharasch method (because of salt formation), but for a variety of chemical reasons it is estimated as highly electronegative. Complications arising from tertiary amine-Grignard reagent complex formation may affect quantitatively, but apparently do not alter qualitatively, the character of the radical.

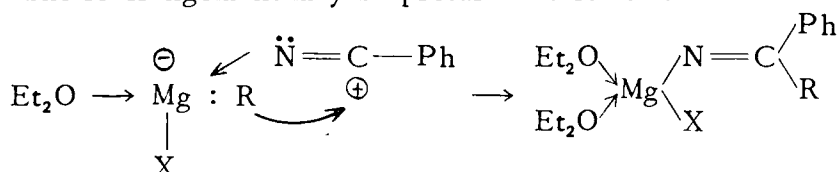
⁵Gilman, St. John, St. John, and Lichtenwalter, *Rec. trav. chim.*, 55, 577-85 (1936).

⁶Kharasch and Weinhouse, *J. Org. Chem.*, 1, 209-30 (1936).

⁷Swain, *J. Am. Chem. Soc.*, 69, 2306-9 (1947).

ethane, demonstrating that the 'salts' of ethane (considered as a very weak acid) are less stable at equilibrium than the 'salts' of benzene. In many reactions, including metalation, cleavage of ether, and reaction with benzophenone, it is furthermore found that ethylmagnesium or *n*-butylmagnesium bromide reacts faster than phenylmagnesium bromide. However, here, in the nitrile reaction, we have the opposite series of reactivity of different Grignard reagents.

"The following mechanism, on the other hand, is consistent with the kinetic order and all reported series of relative reactivity. A complex between reagent and addend* is formed rapidly and reversibly, though very possibly in low concentration at equilibrium relative to the total concentration of Grignard reagent. The rate-determining step consists of an *intramolecular* rearrangement of the complex, in which the radical attached to the metal migrates, with its pair of electrons, to the nitrile carbon. The rearrangement may be pictured as follows.



"There is evidence for this mechanism in the fact that the series of decreasing relative reactivities with benzonitrile of Grignard reagents with different organic radicals is the same, as far as the data overlaps, as the series of decreasing migration aptitudes of these same radicals in the pinacol rearrangement,⁸ which is believed to proceed by intramolecular shift of the radical with its electron pair."

PREPARATIVE PROCEDURES

It is known from general experience and from competition experiments⁹ that nitriles (RCN) are, in general, less reactive toward Grignard reagents than are the corresponding RCHO, R₂CO, RNCO, RCOX, and RCO₂R' compounds. Preparative procedures, therefore, often involve prolonged heating, or the use of high-boiling solvents, or both. However, the reaction rates for individual nitrile-Grignard reagent pairs vary widely, and some reactions are even described as "vigorous." As might be predicted by theoretical extension of Gilman's¹⁰ limited relative reactivity

* (Footnote inserted by present authors)—Direct evidence of complex formation was obtained by Kohler, *Am. Chem. J.*, 35, 386-404 (1906), in the case of the interaction of the non-"acidic" α -phenylcinnamonnitrile with ethylmagnesium bromide. "The primary product is always a dark-red substance that is soluble in ether, but insoluble in ligroin, from which it separates as a paste. On treatment with water it gives ethane, unchanged nitrile, and magnesium salts. It is, therefore, a double compound containing the nitrile in place of ether."

⁸ Bennett and Chapman, *Annual Reports on the Progress of Chemistry*, 27, 118 (1930).

⁹ See, e.g.: Entemann and Johnson, *J. Am. Chem. Soc.*, 55, 2900-3 (1933).

¹⁰ Gilman and Lichtenwalter, *Rec. trav. chim.*, 55, 588-90 (1936).

series, the aliphatic nitriles (with less "electronegative" radicals), are, in general, more reactive toward Grignard reagents than are the aromatic nitriles (with more "electronegative" radicals). Descriptions of some representative illustrative preparations are here assembled.

Kaufmann *et al.*¹¹ have prepared several quinolyl and isoquinolyl ketones in relatively good yields. Their procedure for methylmagnesium iodide and 2-cyanoquinoline is described as follows. Methylmagnesium iodide solution (2.25 equivalents*) is dropped slowly into a well-cooled benzene-ether solution of 2-cyanoquinoline. The reaction is unusually energetic. The reaction product separates as a light-yellow granular precipitate. Without warming, the product is separated from the liquid and is decomposed with water and ammonium chloride. By steam distillation the ketone is isolated as a colorless oil which soon crystallizes. The yield is 79%.

Moureu and Mignonac¹² employed several modifications of method in the preparation of their ketimine hydrochlorides, but the following will serve for example. To a solution of phenylmagnesium bromide, prepared from 4.8 g. of magnesium and 32 g. of bromobenzene in about 85 ml. of ethyl ether, is added 15 g. of benzonitrile dissolved in its own volume of ethyl ether. A white powder appears, and the reaction mixture is refluxed for eight hours. The solid reaction-product mixture is separated and washed thoroughly with four portions of ether. Re-suspended in ether it is treated at -10° with a mixture of crushed ice and ammonium chloride. The ether layer is thoroughly dried over anhydrous sodium sulfate, and is then saturated (while agitated and cooled) with dry hydrogen chloride. The precipitated ketimine hydrochloride is separated by centrifugation and is then washed several times with ether. The reported yield is 27 g. (85.2%).

Several ketones have been prepared by Shriner and Turner¹³ by the reaction of phenylmagnesium bromide with alkyl nitriles. Except for isocaproitrile (yield, 50%), the yields range from 70% (for acetonitrile) to 91% (for propionitrile). They describe a typical procedure as follows.

"The phenylmagnesium bromide is prepared in the usual way from 25 g. of magnesium turnings and 160 g. of bromobenzene in 300 ml. of dry ether. A solution of 0.25 mole of the nitrile in 100 ml. of dry ether is run in slowly with stirring during a period of fifteen minutes. The solution is stirred for an hour longer and allowed to stand overnight. The mixture is poured onto 500 g. of ice and 300 ml. of concentrated hydrochloric acid. The water layer, which contains the hydrochloride of the ketimine, is separated from the ether layer and refluxed vigorously for one hour. The solution is cooled and extracted with four 200-ml. por-

¹¹ Kaufmann, Dandliker, and Burkhardt, *Ber.*, 46, 2929-35 (1913).

* One equivalent of Grignard reagent forms a tertiary-amine complex with the quinolyl nitrogen atom; the other reacts with the cyano group.

¹² Moureu and Mignonac, *Ann. chim.*, [9], 14, 322-59 (1920).

¹³ Shriner and Turner, *J. Am. Chem. Soc.*, 52, 1267-9 (1930).

tions of ether. The ether extract is dried over anhydrous calcium chloride and the ether is distilled from a water-bath. The residue is transferred to a small modified Claisen flask and vacuum-distilled."

Some ketimine hydrochlorides are not only surprisingly resistant to acid hydrolysis but relatively insoluble in cold water. Examples are those prepared from *o*-chlorobenzonitrile and 8-methyl-1-naphthylmagnesium bromide by Fieser and Seligman,¹⁴ and from 4-cyano-7-isopropylhydrindene and α -naphthylmagnesium bromide by Bruce and Todd.¹⁵

"The Grignard reagent from 66 g. of 1-bromo-8-methylnaphthalene was mixed with 26 g. of *o*-chlorobenzonitrile in benzene, and after refluxing for sixteen hours, dilute hydrochloric acid was added, and the crystalline ketimine hydrochloride was collected and washed with cold water, alcohol, and ether; yield, 60 g. (63%). This salt, which is moderately soluble in hot water, was recovered after refluxing with hydrochloric acid at various concentrations."¹⁴

"To the Grignard reagent prepared from 22 g. of α -bromonaphthalene, 3 g. of magnesium and 80 ml. of ether, was added 50 ml. of benzene and 13 g. of 4-cyano-7-isopropylhydrindene. After the reaction mixture was heated overnight it was poured on 100 g. of ice with 50 ml. of hydrochloric acid. After two hours 25 g. of the ketimine hydrochloride, a yellow, crystalline solid, was collected on a filter. A sample crystallized from 70% acetic acid melted at 262° with decomposition; yield, 100%."¹⁵

A method of preparing more water-sensitive ketimine salts is described by Cloke,¹⁶ whose procedure may be summarized as follows. Ethylmagnesium bromide was first prepared in the usual manner from 42.3 g. of ethyl bromide, 9 g. of magnesium and 150 ml. of anhydrous ether. To this ethereal solution 10.35 g. of isopropyl cyanide in three times its volume of ether was added slowly from a dropping funnel. The material was then boiled gently for about twelve hours, when it was transferred to a separatory funnel, from which it was added slowly to about 300 ml. of liquid ammonia in a 500-ml. Dewar flask, which was then connected with a five-foot lime tower. From time to time during a twenty-hour period the mixture was agitated to disintegrate lumps. At this point 200 ml. of dry ether was added, and the solution was filtered through a Buchner funnel in a moisture-proof apparatus. After removal of residual ammonia with a stream of dry air the solution was somewhat diluted with ether and treated with dry hydrogen chloride. Purification was effected by solution in a mixture of acetic acid (*ca.* 50 ml.) and acetic anhydride (*ca.* 5 ml.) and reprecipitation with dry ether; yield, 10 g. (48.5%).

The preparation of a series of alkyl α -naphthyl ketones in yields ranging from 37 percent to 63 percent is described by Nunn and Henze¹⁷ as follows.

¹⁴Fieser and Seligman, *J. Am. Chem. Soc.*, 61, 136-42 (1939).

¹⁵Bruce and Todd, *J. Am. Chem. Soc.*, 61, 157-61 (1939).

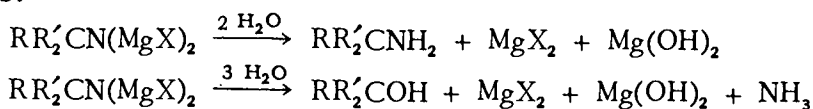
¹⁶Cloke, *J. Am. Chem. Soc.*, 62, 117-9 (1940).

¹⁷Nunn and Henze, *J. Org. Chem.*, 12, 540-2 (1947).

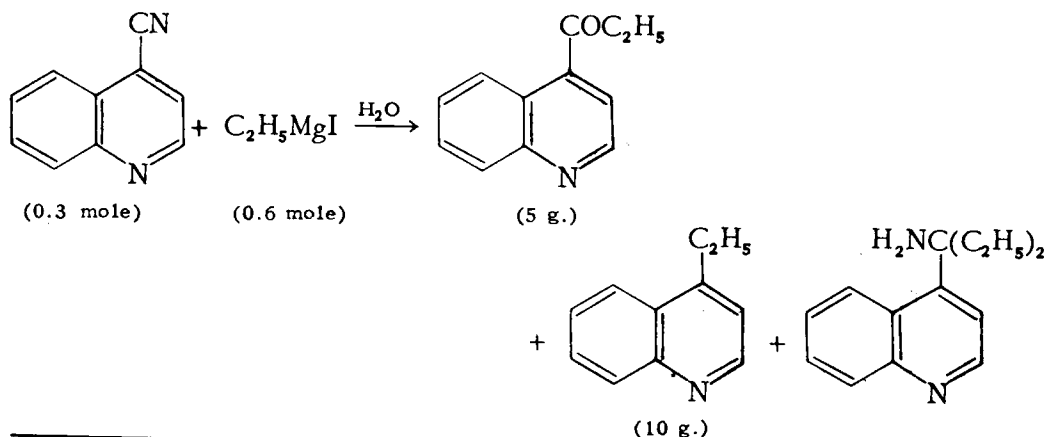
"To a Grignard reagent prepared from magnesium turnings (0.21 g.-atom) and an alkyl bromide (0.22 mole) in 250 ml. of anhydrous ether, α -naphthonitrile (0.20 mole) in 300 ml. of anhydrous toluene was added over a period of one hour with continuous stirring. The ether was removed by distillation, and the toluene solution was refluxed for five hours. After cooling, the ketimine was obtained by hydrolysis of the toluene solution with 100 ml. of saturated ammonium chloride and chipped ice. The aqueous layer was then separated from the toluene solution and extracted once with ether. The ether and toluene extracts were combined and extracted twice with 100-ml. portions of dilute sulfuric acid. These two acid extracts were combined, extracted once with ether, and heated at reflux temperature for two hours, cooled, and extracted twice with an ether-benzene mixture. The ether-benzene extracts were washed with water, twice with saturated sodium bicarbonate solution, and twice with saturated sodium chloride solution. The ether-benzene layer was then concentrated and distilled under diminished pressure."

t-ALKYLAMINE (OR TERTIARY ALCOHOL) FORMATION

For the most part the initial product of reaction between a nitrile and a Grignard reagent displays little or no tendency to react further with the Grignard reagent. Apparently the halomagnesium ketimine derivatives are, in general, for solubility or other reasons, less reactive than the parent nitriles. In a few instances, however, products which cannot be readily accounted for in any other manner have been reported. In all such cases the product of the Grignard reaction itself is presumably a compound of the general formula $RR'_2CN(MgX)_2$. The products isolated after hydrolysis are, in some cases, *t*-alkylamines, and in others, tertiary alcohols.

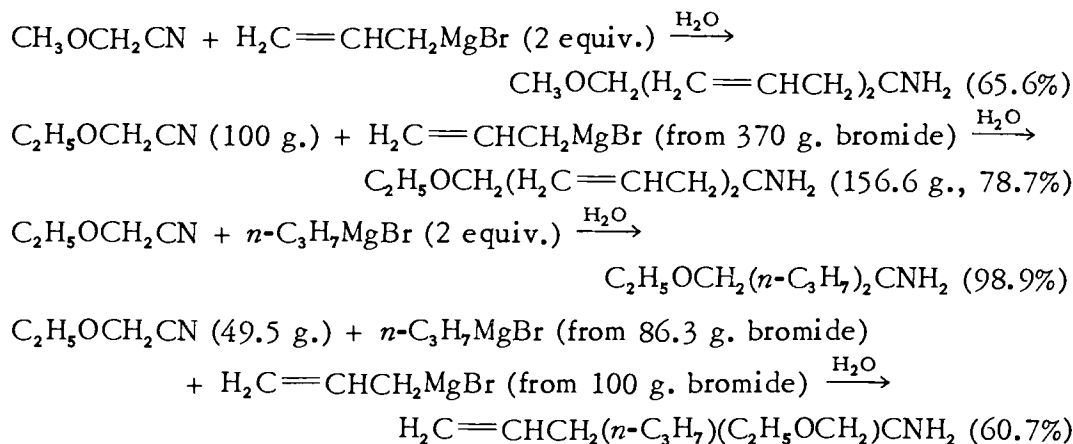


The isolation of 3-amino-3- γ -quinolylpentane as one of the byproducts in the intended preparation of 4-propionylquinoline from 4-cyanoquinoline and ethylmagnesium iodide was reported by Rabe and Pasternack.¹⁸



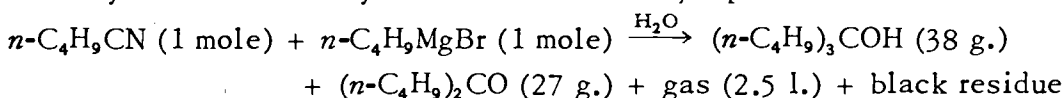
¹⁸Rabe and Pasternack, *Ber.*, 46, 1026-32 (1913).

Allen and Henze,¹⁹ attempting the preparation of alkoxymethyl ketones, rediscovered this reaction, and (evidently regarding it as new) employed it to prepare in excellent yields some otherwise difficultly accessible alkoxymethyldialkylamines.



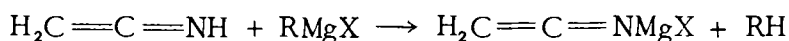
The stepwise reaction, leading to the formation of a potentially optically active amine, would seem to leave little doubt that the course of the reaction is as represented.

Baerts²⁰ has detected small quantities (*ca.* 1%) of tertiary alcohols among the products of the reactions of propio- and butyronitriles with ethylmagnesium bromide. A similar report is made by Bruylants and Mathus²¹ concerning the reaction of low-boiling α -butenitrile (1-cyanopropene) with ethylmagnesium bromide. In the reaction of *n*-butylmagnesium bromide with valeronitrile, conducted in methylal, Bourgom²² actually found the tertiary alcohol to be the major product.



KETENIMINATE FORMATION

Nitriles with labile hydrogen atoms attached to the *alpha* carbon atom are capable of undergoing with Grignard reagents a reaction analogous to a ketone enolization (*q.v.*, Chapter VI). Bruylants,²³ in discussing the reactions of acetonitrile with aliphatic Grignard reagents, postulates that the nitrile reacts primarily as a "pseudo-acid."



If the nitrile is in fact in equilibrium with a "pseudo-acidic" tautomer the reaction suggested would undoubtedly take place. It seems alto-

¹⁹ Allen and Henze, *J. Am. Chem. Soc.*, 61, 1790-4 (1939).

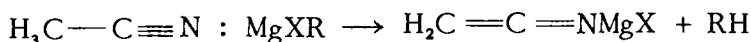
²⁰ Baerts, *Bull. soc. chim. Belg.*, 31, 184-92, 421-6 (1922).

²¹ Bruylants and Mathus, *Bull. acad. roy. Belg., Classe sci.*, [5], 11, 636-53 (1925); *Chem. Zentr.*, 1926, I, 3145.

²² Bourgom, *Bull. soc. chim. Belg.*, 33, 101-15 (1924).

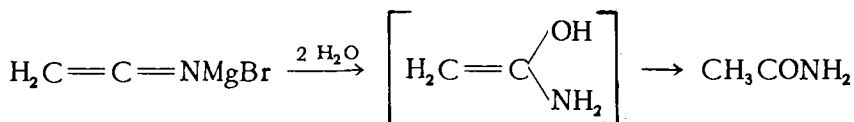
²³ Bruylants, *Bull. acad. roy. Belg., Classe sci.*, [5], 8, 7-23 (1922); *Chem. Zentr.*, 1923, I, 85.

gether possible (indeed, highly probable), however, that keteniminate formation may take place (similarly to analogous enolate formation) by attack of the Grignard reagent upon the normal cyano form of the molecule.



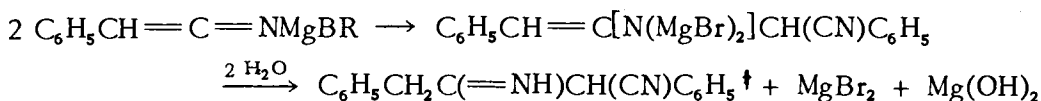
If this is in fact the case, then the complex decomposition leading to keteniminate formation is competitive with the complex rearrangement leading to "normal" addition-product formation. In view of the established relative reactivities of Grignard reagents toward benzonitrile (in the "normal" reaction) it is of interest in this connection, though, of course, not critically conclusive, that phenylmagnesium bromide is reported as reacting with acetonitrile to give moderate to fairly good yields of the "normal" product (acetophenone),²⁴ whereas the aliphatic Grignard reagents yield no normal product at all [Bruylants (*loc. cit.*²³), Mignonac and Hoffmann²⁵].

Amide formation. According to Mignonac and Hoffmann (*loc. cit.*²⁵), the initial product (other than ethane) of the reaction of acetonitrile with ethylmagnesium bromide, upon treatment with water at 0°, yields acetamide.



The presence, subsequent to hydrolysis, of phenylacetamide among the products of the reaction of phenylacetonitrile with methylmagnesium bromide²⁶ may be similarly explained.*

Condensation and polymerization. Rondou (*loc. cit.*²⁶) attributes the formation of the dimer of phenylacetonitrile to the interaction of two molecules of keteniminate.



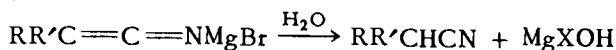
However, on the basis of analogy with the ketolization reaction, it seems more probable that the condensation involves one molecule of keteniminate and one molecule of nitrile, as Bruylants (*loc. cit.*²³) has assumed in the case of acetonitrile.

²⁴Shriner and Turner, *J. Am. Chem. Soc.*, 52, 1267-9 (1930); Troger and Beck, *J. prakt. Chem.*, [2], 87, 289-311 (1913); Bary, *Bull. soc. chim. Belg.*, 31, 397-410 (1922).

²⁵Mignonac and Hoffmann, *Compt. rend.*, 191, 718-20 (1930).

²⁶Rondou, *Bull. soc. chim. Belg.*, 31, 231-41 (1922).

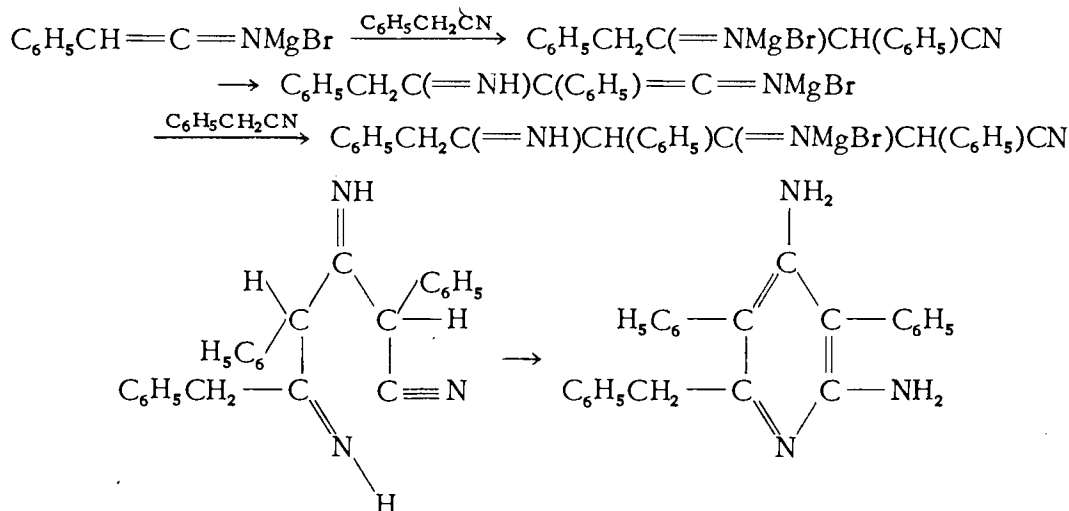
*It is, of course, probable that in many cases simple hydrolysis, without the addition of water, may regenerate the nitrile.



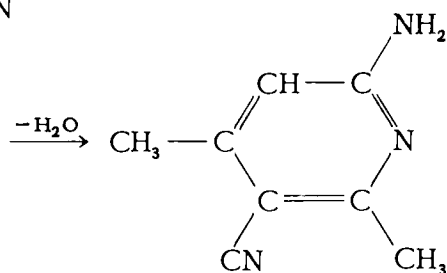
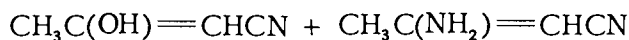
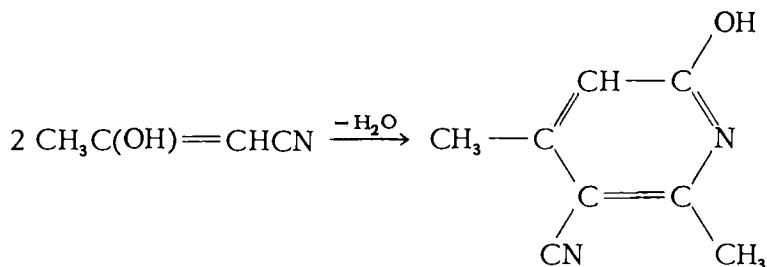
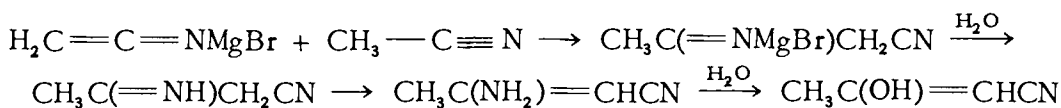
†The assignment of structure of the dimer is made on the basis of its identity with the dimer of von Meyer, *J. prakt. Chem.*, 52, 81-117 (1895), obtained by the action of sodium on the nitrile, and shown to yield an isoöxime identical with that obtained from α-cyanodesoxybenzoïn [$\text{C}_6\text{H}_5\text{CH}_2\text{COCH}(\text{CN})\text{C}_6\text{H}_5$].



The trimer of phenylacetonitrile is formulated by Rondou (*loc. cit.*²⁶) as 2,4-diamino-3,5-diphenyl-6-benzylpyridine, and is assumed by him to result from the reaction of two molecules of keteniminate with one of nitrile. It would seem, however, quite as logical to attribute its formation to successive condensations of a molecule of keteniminate with a molecule of nitrile, and of the secondary keteniminate thus formed with a second molecule of nitrile, followed by ring closure, either before or during hydrolysis.

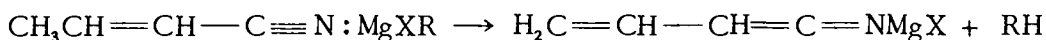


Bruylants (*loc. cit.*²³) has isolated from among the reaction products of acetonitrile with an aliphatic Grignard reagent two compounds which he characterizes as 2-hydroxy-4,6-dimethyl-5-cyanopyridine and 2-amino-4,6-dimethyl-5-cyanopyridine, respectively. He accounts for their formation as follows.



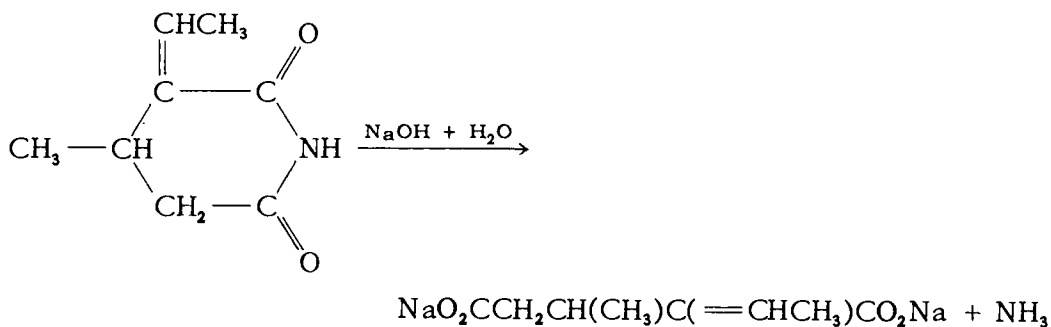
The formation of various other nitrile condensation products may be accounted for in accordance with the principles outlined.

At first glance it might appear that the foregoing discussion does not elucidate the Grignard condensations of the crotononitriles ($\text{CH}_3\text{CH}=\text{CHCN}$). Although the crotononitriles are the more stable of the buteno-nitrile isomers (96–100% at equilibrium),²⁷ the interconversion of the α,β - and β,γ -unsaturated nitrile isomers in the presence of suitable catalysts is rather rapid.²⁸ To account for the Grignard condensation of the crotononitriles it is sufficient to make only three rather probable assumptions: (1) that at equilibrium at ordinary temperatures there is a finite concentration of the β,γ -unsaturated isomer; (2) that the Grignard reagent (or some component of the Grignard reagent solution) is a suitable catalyst for the interconversion of isomers; and (3) that keteniminate formation is rapid as compared with "normal" addition. However, not all of even these rather probable assumptions may be necessary. It is conceivable, at least, that the Grignard reagent is capable of effecting a direct conversion of α,β -unsaturated isomer to keteniminate, thus by-passing β,γ -unsaturated isomer formation entirely.



In that case it would be necessary to assume only that the nitrile-keteniminate conversion is rapid as compared with "normal" addition.

It may be noted in passing that, according to Bruylants and Gevaert,²⁹ the dimeric condensation product of the reaction of ethylmagnesium bromide with crotononitrile is identical with that similarly obtained from allyl cyanide and with that obtained by von Meyer^{29,1} by the treatment of allyl cyanide with sodium or with sodium ethoxide.



CYANO GROUP DISPLACEMENT

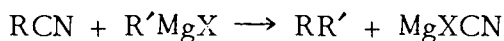
Replacement by organic radical of Grignard reagent. The ability of the cyano group to behave, under certain conditions, as a "pseudo-halogen" is illustrated by the Grignard reactions of some nitriles.

²⁷ Letch and Linstead, *J. Chem. Soc.*, 1932, 443–56.

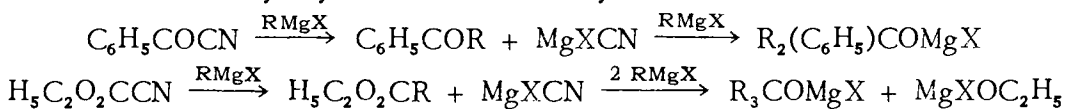
²⁸ Ingold, Salas, and Wilson, *J. Chem. Soc.*, 1936, 1328–34.

²⁹ Bruylants and Gevaert, *Bull. acad. roy. Belg., Classe es sciences*, [5], 9, 27–37 (1923); *Chem. Zentr.*, 1923, III, 1263.

^{29,1} von Meyer, *J. prakt. Chem.*, 52, 81–117 (1895).

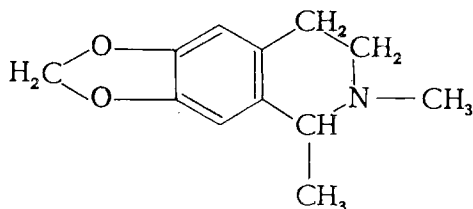
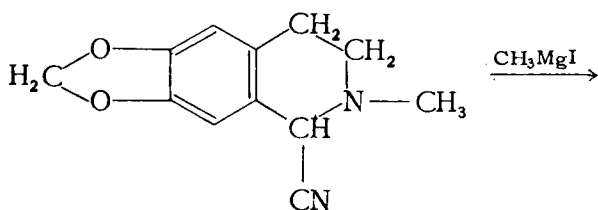


Although this type of reaction has not been exhaustively investigated, it appears to be fairly general for α -amino³⁰ and α,α -disubstituted cyano-hydrins.³¹ It must also be the initial step in the formation of tertiary alcohols from benzoyl cyanide³² and from cyanoformic ester.³³



The range of cyano compounds represented in the foregoing summary is scarcely broad enough to justify any very dogmatic generalizations, yet two characteristics are common to the radicals attached to the cyano group— $(\text{CH}_2)_5\text{NCH}_2$, $(\text{CH}_3)_2\text{NCH}_2$, $\text{C}_6\text{H}_5\text{NHCH}_2$, $\text{R}(\text{CH}_2)_5\text{NCH}$, $\text{R}(\text{CH}_3)_2\text{NCH}$, $\text{RR}'(\text{CH}_2)_5\text{NC}$, $\text{RR}'(\text{CH}_3)_2\text{NC}$, $\text{RR}'(\text{HO})\text{C}$, $\text{C}_6\text{H}_5\text{CO}$, $\text{H}_2\text{C}_5\text{O}_2\text{C}$. (1) All would be estimated as rather weakly "electronegative" in the Kharasch sense. (2) None are capable of any considerable degree of resonance stabilization as free radicals. It may reasonably be assumed, therefore, that in all these cases the radical-cyano bond has a rather high degree of ionic character, with the negative end of the dipole at the cyano group.

The behavior of 1-cyanohydrastinine (Stevens *et al.*, *loc. cit.*^{30d,e}) may be explained on the grounds of its constitutional similarity to the α -amino nitriles already discussed, as may that of 9,10-dimethyl-10-cyano-9,10-dihydroacridine (Stevens *et al.*, *loc. cit.*³⁰) if the principle of vinylology be invoked.

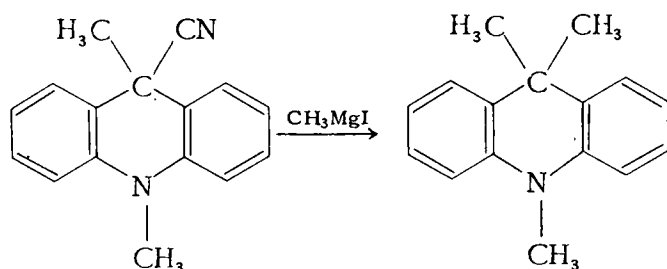


³⁰(a) Christiaen, *Bull. soc. chim. Belg.*, 33, 483-90 (1924); (b) Bruylants, *Bull. acad. roy. Belg., Classe sci.*, [5], 11, 261-80 (1925); *Chem. Zentr.*, 1926, I, 874; (c) Velghe, *ibid.*, [5], 11, 301-8 (1925); *Chem. Zentr.*, 1926, I, 875; (d) Stevens, Cowan, and MacKinnon, *J. Chem. Soc.*, 1931, 2568-72; (e) Thomson and Stevens, *ibid.*, 1932, 2607-12.

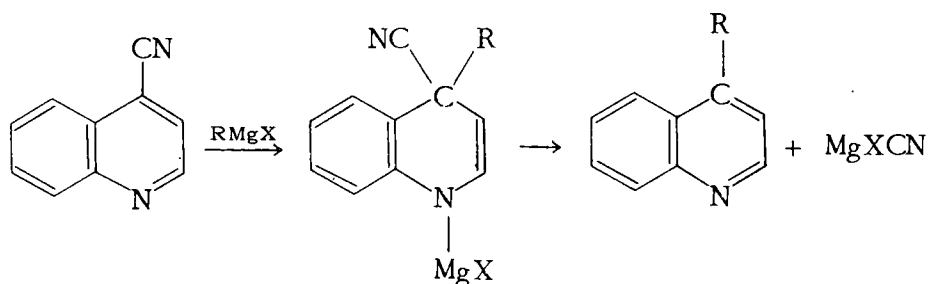
³¹Guerden, *Bull. acad. roy. Belg., Classe sci.*, [5], 11, 701-10 (1925); *Chem. Zentr.*, 1926, I, 3146.

³²Adams, Bramlet, and Tendick, *J. Am. Chem. Soc.*, 42, 2369-74 (1920); de Coster, *Bull. acad. roy. Belg., Classe sci.*, [5], 11, 661-5 (1925); *Chem. Zentr.*, 1926, I, 3146.

³³Bruylants, *Bull. acad. roy. Belg., Classe sci.*, [5], 10, 392-5 (1924); *Chem. Zentr.*, 1924, II, 2457; McKenzie and Duff, *Ber.*, 60B, 1335-41 (1927).



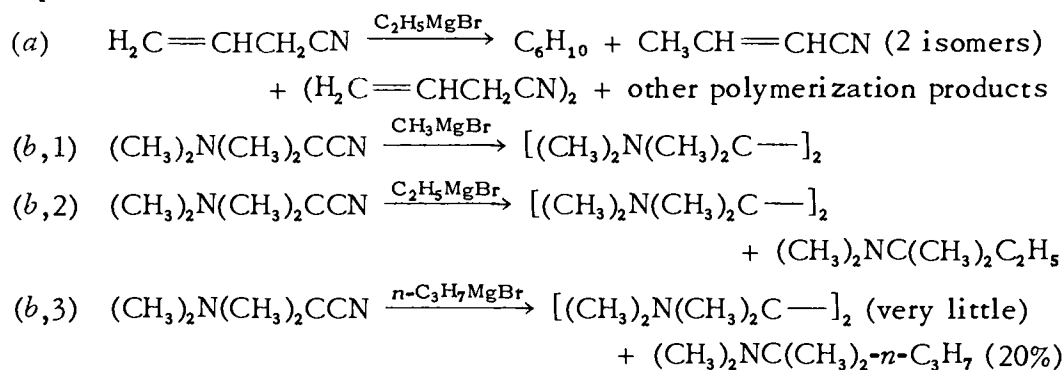
The formally similar behavior of 4-cyanoquinoline, is, perhaps, somewhat different. Rabe and Pasternack³⁴ regarded it as an example of a special type of 1,4-addition reaction.



Vinylologists, however, will detect here an analogy with the cyanogen reactions (*q.v.*).

Somewhat resembling these reactions formally, and analogous to the methoxyl group displacements previously discussed (see Chapter VI, Cleavages Involving 1,6-Addition), are the reactions of 4-cyanobenzoyldurene* reported by Fuson *et al.*³⁵

Coupling. A few examples of a reaction analogous (formally, at least) to the coupling reactions of aralkyl halides (*q.v.*, Chapter XVI) have been reported.³⁶

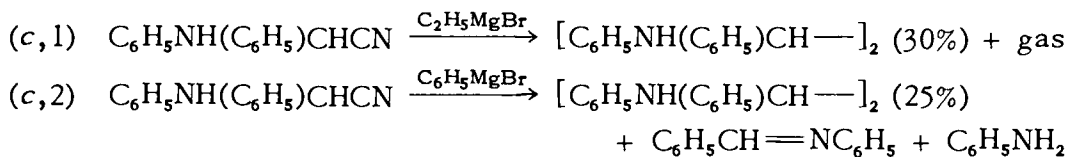


³⁴Rabe and Pasternack, *Ber.*, 46, 1026-32 (1913).

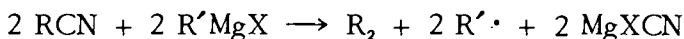
* The corresponding 3-cyano compound reacts "normally" to form diketones. The 2-cyano isomer forms 1,1-disubstituted 3-durylpseudoisindoles. (See Table VI-XVIII, $\text{C}_{18}\text{H}_{17}\text{ON}$ and Table X-I, $\text{C}_{18}\text{H}_{17}\text{NO}$.)

³⁵Fuson, Emmons, and Tull, *J. Org. Chem.*, 16, 648-54 (1951).

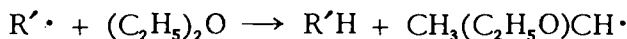
³⁶(a) Bruylants and Gevaert, *Bull. acad. roy. Belg., Classe sci.*, [5], 9, 27-37 (1923); *Chem. Zentr.*, 1923, III, 1263; (b) Velghe, *ibid.*, [5], 11, 301-8 (1925); *Chem. Zentr.*, 1926, I, 875; (c) Christiaen, *Bull. soc. chim. Belg.*, 33, 483-90 (1924).



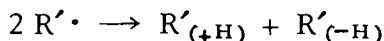
Unfortunately no attention has been paid to the fate of the organic radicals of the Grignard reagents. If these reactions are indeed similar to the halide coupling reactions one may describe the overall process as:



When the Grignard reagent is methyl it would be converted almost quantitatively to the corresponding hydrocarbon by the capture of a hydrogen atom from the solvent.



Ethyl and propyl radicals, while they might react to a very slight extent in this way, would, for the most part, disproportionate



The fact that reaction *c, 1* is reported as evolving "gas" cannot be regarded as confirmatory of the reaction scheme proposed, for this reaction is undoubtedly complicated by keteniminate formation.

Moreover, it is to be noted that none of the Grignard reagents involved in the examples cited is of the type that shows a tendency toward homolytic dissociation. If these are, like the halide coupling reactions, free-radical chain-reactions they must, in the instances cited, be attributed to the influence of metallic impurities in the magnesium employed for Grignard reagent preparation or to other (unrecognized) free-radical chain-initiating factors.

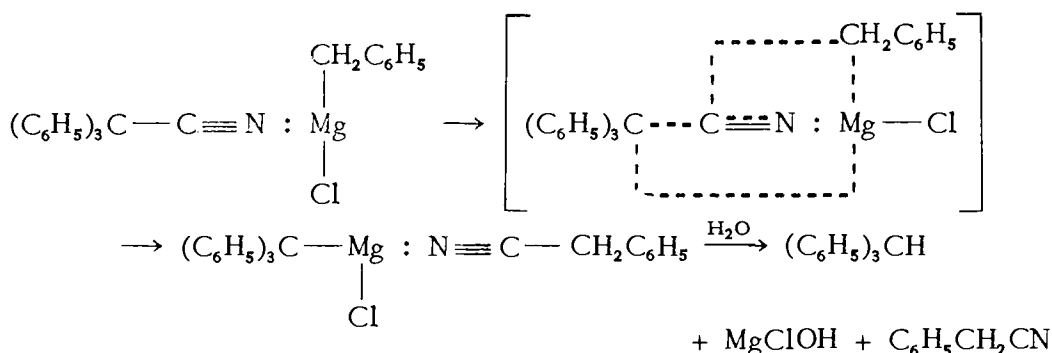
Reductive displacement. In view of the extremely limited data available concerning reactions in which the cyano group of the nitrile is replaced by a hydrogen atom (*i.e.*, by the MgX group of the Grignard reagent), any attempt at their elucidation must be regarded as speculative and tentative. In the most clear-cut example reported,³⁷ that of the reaction of triphenylmethyl cyanide with benzylmagnesium chloride, a 70 per cent yield of triphenylmethane is recorded. Some bibenzyl was also isolated, but no evidence is advanced that this had any other source than the Wurtz side-reaction which accompanies the preparation of the Grignard reagent.

By theoretical extension of the relative reactivity studies of Gilman *et al.*,³⁸ it would appear that the Werner complex of the nitrile and Grignard reagent in question must be of an exceptionally unreactive type (as regards the "normal" addition reaction), for both the radical R of the nitrile

³⁷ Ramart-Lucas and Salmon-Legagneur, *Bull. soc. chim.*, [4], 43, 321-9 (1928).

³⁸ Gilman and Lichtenwalter, *Rec. trav. chim.*, 55, 588-90 (1936); Gilman, St. John, St. John, and Lichtenwalter, *ibid.*, 55, 577-85 (1936).

(RCN) and the radical R' of the Grignard reagent ($R'MgX$) are weakly electronegative (the former extremely so). Moreover, both radicals (especially the former) are capable of a considerable degree of resonance stabilization. On this basis one might confidently predict that at relatively low temperatures (e.g., that of boiling ether) the type of complex rearrangement leading to "normal" addition would take place extremely slowly or not at all. One might then consider the probability of a competitive rearrangement, and the possibility that such a rearrangement might differ from the essentially ionic rearrangement leading to exchange of the organic radical of the Grignard reagent for the cyano group of the nitrile. A type of rearrangement that accounts for the major product reported, and which seems not unlikely in view of the outlined characteristics of the complex components may be crudely represented (without implication as to mechanistic detail) as follows.



The process represented is a radical rearrangement, although the actual liberation of free radicals into the solution is not implied. Perhaps it should be represented as an equilibrium, but the high yield of triphenylmethane liberated upon hydrolysis indicates that the equilibrium, if it exists, is substantively toward the right. The prehydrolysis product postulated is identical with the Werner complex which might be expected to result from the combination triphenylmethylmagnesium chloride and phenylacetonitrile—another presumably exceptionally unreactive complex (as regards "normal" addition). Unfortunately, no one has as yet applied the critical test of adding an equivalent of a suitable Grignard reagent co-reactant to such a reaction mixture, nor has anyone investigated the products of reaction in higher-boiling solvents.

Benzoyldiphenylmethyl cyanide is reported to react similarly with benzylmagnesium chloride (Ramart-Lucas, *loc. cit.*³⁷).

The reactions of dimethyl- and dibenzylmalononitriles with phenylmagnesium bromide have been studied by Erickson and Barnett.³⁹ They call attention to the formal similarity between these reactions and the Grignard cleavage reactions of disubstituted malonic esters,⁴⁰ α -oxido ketones and glycidic esters,⁴¹ and of β -diketones.⁴² They propose reaction

³⁹ Erickson and Barnett, *J. Am. Chem. Soc.*, 57, 560-2 (1935).

⁴⁰ Leroide, *Ann. chim.*, [9], 16, 354-410 (1921).

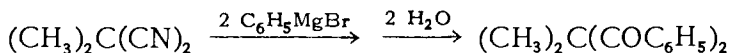
⁴¹ Kohler, Richtmyer, and Hester, *J. Am. Chem. Soc.*, 53, 205-21 (1931).

⁴² Kohler and Erickson, *J. Am. Chem. Soc.*, 53, 2301-9 (1931).

schemes in which the initial products are "normal" cyano-Grignard reagent addition products which either rearrange or react further with the Grignard reagent.

Although the radicals $\text{NC}(\text{C}_6\text{H}_5\text{CH}_2)_2\text{C}$ and $\text{NC}(\text{CH}_3)_2\text{C}$ are probably neither so weakly "electronegative" nor capable of so high a degree of resonance stabilization as the radicals $(\text{C}_6\text{H}_5)_3\text{C}$ and $\text{C}_6\text{H}_5\text{CH}_2(\text{C}_6\text{H}_5)_2\text{C}$, they unquestionably share those characteristics to some extent.

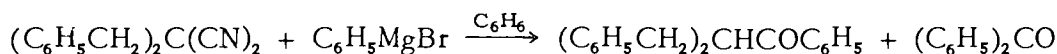
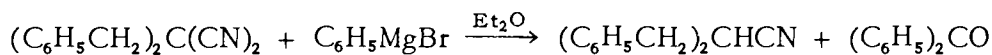
Dimethylmalononitrile, with the less weakly "electronegative" radical $\text{NC}(\text{CH}_3)_2\text{C}$, reacts in part "normally" when added to an excess of ethereal Grignard reagent at ordinary temperatures.



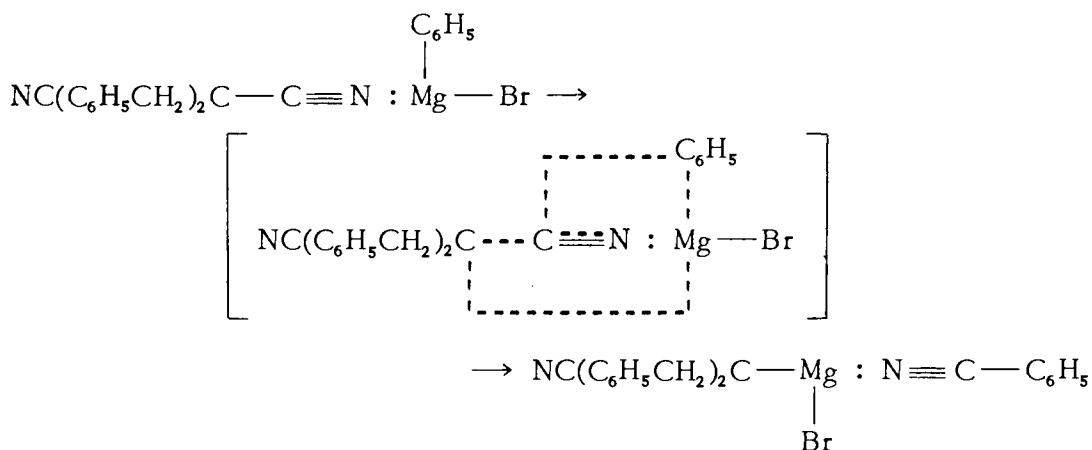
However, some benzophenone is also found, so there must be some simultaneous cleavage.

When one equivalent of ethereal Grignard solution is combined (by reverse addition) with one equivalent of ethereal nitrile at -15° , only the cleavage products, $(\text{CH}_3)_2\text{CHCN}$ and $\text{C}_6\text{H}_5\text{CN}$, are isolated upon hydrolysis.

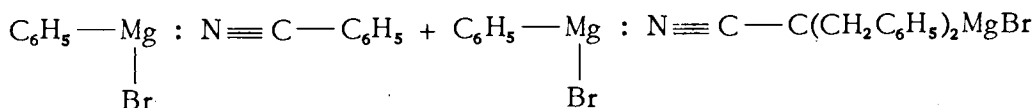
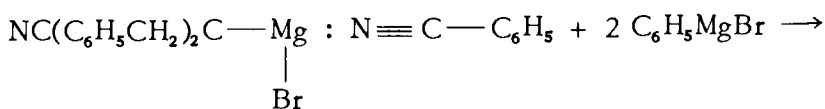
Dibenzylmalononitrile, with the more weakly electronegative radical $\text{NC}(\text{C}_6\text{H}_5\text{CH}_2)_2\text{C}$, gives only cleavage products, or their further reaction products, both in ether and in the higher-boiling benzene.



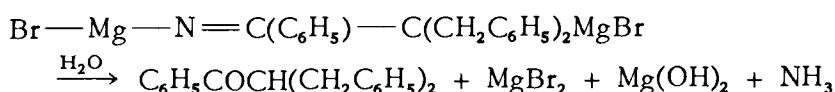
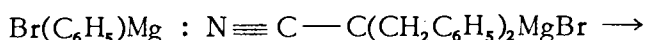
A scheme similar to that proposed for the triphenylmethyl cyanide reaction would account adequately for these phenomena. In the former case the rearrangement of a complex of one relatively unreactive Grignard reagent with a relatively unreactive nitrile to form the complex of another relatively unreactive Grignard reagent with another relatively unreactive nitrile was postulated. In the present instance the rearrangement would convert the complex of a relatively reactive Grignard reagent with a relatively unreactive nitrile to the complex of a relatively unreactive Grignard reagent with a relatively reactive nitrile.



In the presence of excess Grignard reagent new complexes would be formed.

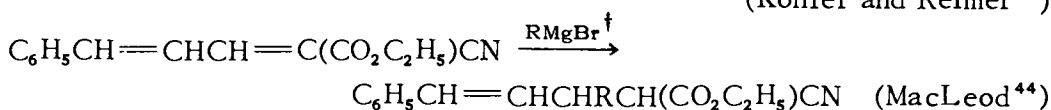
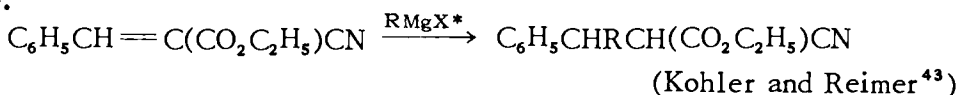


Although this is potentially an equilibrium process, which would, of course, include also the etherate of the Grignard reagent, at ordinary temperatures the relatively reactive $\text{C}_6\text{H}_5\text{BrMg} : \text{NCC}_6\text{H}_5$ complex would be removed by "normal" addition-reaction rearrangement to form the ketimine of benzophenone. At higher temperatures the other (less reactive) complex might also react, as it evidently does in boiling benzene.

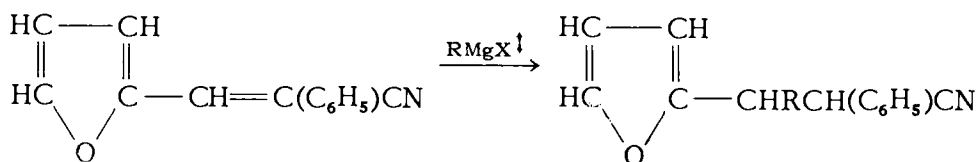
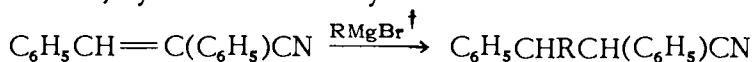


α,β -UNSATURATED NITRILES

Like some of the α,β -unsaturated aldehydes and esters, some of the α,β -unsaturated nitriles undergo 1,4-addition of the Grignard reagent to the conjugated system. The number of examples of reactions of Grignard reagents with α,β -unsaturated nitriles is so limited as to discourage generalization. Indeed, in some of the few cases available for consideration it is a question whether one has to do with 1,4-addition to an α -cyano α,β -unsaturated ester or to an α -carbalkoxy α,β -unsaturated nitrile.



Unequivocal examples of 1,4-addition to α,β -unsaturated nitriles are reported, however, by Kohler⁴⁵ and by Maxim and Aldea.⁴⁶



* R = CH₃, *i*-C₃H₇, C₆H₅, C₆H₅CH₂, C₆H₅C≡C, α -C₁₀H₇.

⁴³ Kohler and Reimer, *Am. Chem. J.*, 33, 333-56 (1905).

[†] R = C₂H₅, C₆H₅.

⁴⁴ MacLeod, *Am. Chem. J.*, 44, 331-52 (1910).

⁴⁵ Kohler, *Am. Chem. J.*, 35, 386-404 (1906).

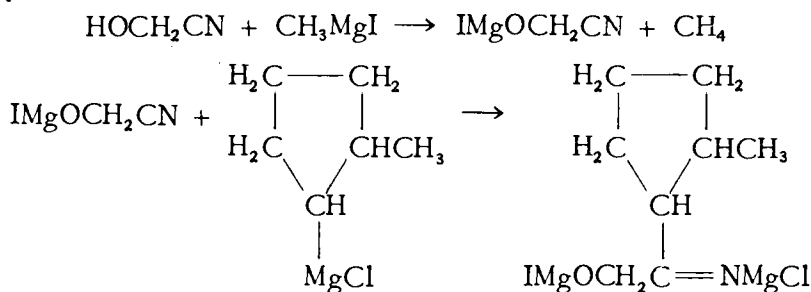
⁴⁶ Maxim and Aldea, *Bull. soc. chim.*, [5], 2, 582-91 (1935); [5], 3, 1329-34 (1936).

[†] R = CH₃, C₂H₅, *n*-C₃H₇, *i*-C₄H₉, *i*-C₅H₁₁, C₆H₅CH₂, *p*-CH₃C₆H₄.

It may be noted that in all the examples cited as undergoing 1,4-addition the nitriles are α -substituted. Presumably, aside from any electronic influence it may exert, the *alpha* substituent presents some degree of steric hindrance to 1,2-addition. That this may be a necessary, but is not always a sufficient, condition for 1,4-addition is indicated by the reported 1,2-addition of phenylmagnesium bromide to $\alpha,2,4,6$ -tetramethyl- β -methoxycinnamionitrile.⁴⁷ In this case steric hindrance to 1,4-addition is presumably considerably greater than that to 1,2-addition. β -Methoxy-2,4,6-trimethylcinnamionitrile is also reported to undergo 1,2-addition (Fuson *et al.*, *loc. cit.*⁴⁷), as are cinnamionitrile and β -phenylcinnamionitrile (Kohler, *loc. cit.*⁴⁵).

CYANOHYDRINS

For the most part cyanohydrins are reported as reacting "normally" with Grignard reagents, although the yields obtained are seldom stated, and in most cases it may be inferred that no attempt at the isolation and identification of byproducts was made. One equivalent of Grignard reagent is first consumed by the highly "active" hydrogen of the hydroxyl group; a second equivalent then reacts with the relatively inert nitrile group. Yarnall and Wallis⁴⁸ have taken advantage of this marked differential in functional reactivities to spare less readily accessible Grignard reagents.



The cleavage reactions of nitriles of the types $\text{R}_2\text{C}(\text{OH})\text{CN}$ and $\text{RR}'\text{C}(\text{OH})\text{CN}$, reported by Guerden,⁴⁹ have already been discussed. That at least some nitriles of this kind also react "normally" to some extent is evidenced by the reported reactions of α -hydroxyisobutyronitrile and α -hydroxyisovaleronitrile with methylmagnesium halides (Gauthier;⁵⁰ see also Guerden, *loc. cit.*⁴⁹).

Weissberger and Glass⁵¹ report a cyanohydrin reaction which at first glance appears to involve a rather peculiar rearrangement. The reaction scheme which they propose, however, appears to account satisfactorily for the product isolated.*

⁴⁷ Fuson, Ulliyot, Stedman, and Tawney, *J. Am. Chem. Soc.*, 60, 1447-50 (1938).

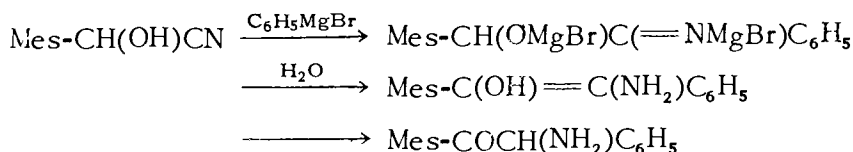
⁴⁸ Yarnall and Wallis, *J. Org. Chem.*, 4, 284-8 (1939).

⁴⁹ Guerden, *Bull. acad. roy. Belg., Classe sci.*, [5], 11, 701-10 (1925); *Chem. Zentr.*, 1926, I, 3146.

⁵⁰ Gauthier, *Compt. rend.*, 152, 1100-2 (1911); *Chem. Zentr.*, 1911, I, 1809.

⁵¹ Weissberger and Glass, *J. Am. Chem. Soc.*, 64, 1724-7 (1942).

* Mes = mesityl = 2,4,6-(CH₃)₃C₆H₂—.



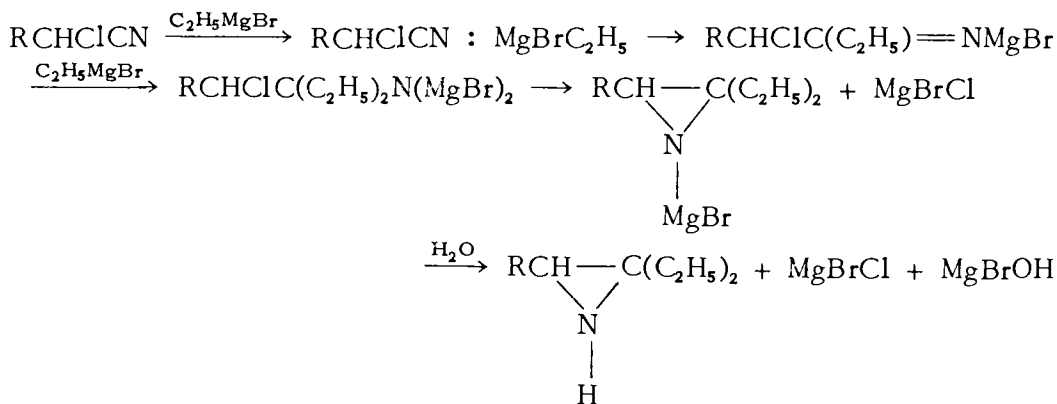
α -HALO NITRILES

The reactions of α -halo nitriles with Grignard reagents have been but little investigated. Although the "normal" reaction of a nitrile with a Grignard reagent apparently differs in mechanism from the "normal" reaction of a ketone with a Grignard reagent, there are (as has already been noted) marked analogies between some of the "abnormal" reactions of the two types of compounds. On this ground one might regard as possibilities (by analogy with the corresponding α -halo ketone reactions, *q.v.*, the following reactions of α -halo nitriles.

- (1) $\text{RR'XCCN} + \text{R''MgX'} \rightarrow \text{RR'XCCR''=NMgX'}$
- (2) $\text{RXCHCN} + \text{R'MgX'} \rightarrow \text{RXC=C=NMgX'} + \text{R'H}$
- (3) $\text{RXCHCN} + \text{R'MgX'} \rightarrow \text{RHC=C=NMgX'} + \text{R'X}$
- (4) $\text{RR'XCCN} + \text{R''MgX'} \rightarrow \text{RR'R''CCN} + \text{MgXX'}$

The nature of the predominating reaction might be expected to vary with: (1) the *alpha* halogen involved, (2) the structure of the α -halo nitrile, and (3) the Grignard reagent involved. Although no extensive or very thorough studies have been made, there is evidence that reactions of the first three types occur.

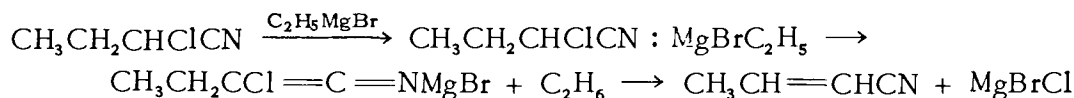
Mathus⁵² has reported a very small yield (1.5%) of phenacyl chloride from the reaction of phenylmagnesium bromide with chloroacetonitrile. The isolation of 1,1-diethyl-2-alkylethylenimines as products of the reactions of α -chloronitriles with ethylmagnesium bromide⁵³ strongly suggests a reaction sequence in which the first step is a "normal" addition at the cyano triple bond.



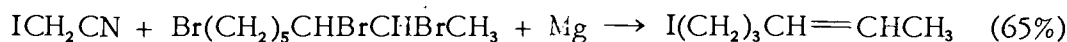
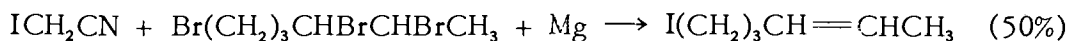
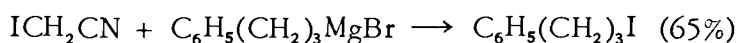
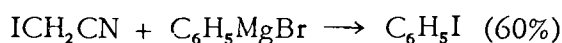
⁵² Mathus, *Bull. soc. chim. Belg.*, 34, 285-9 (1925).

⁵³ de Boosere, *Bull. soc. chim. Belg.*, 32, 25-51 (1923); Theunis, *Bull. acad. roy. Belg., Classe sci.*, [5], 12, 185-96 (1926).

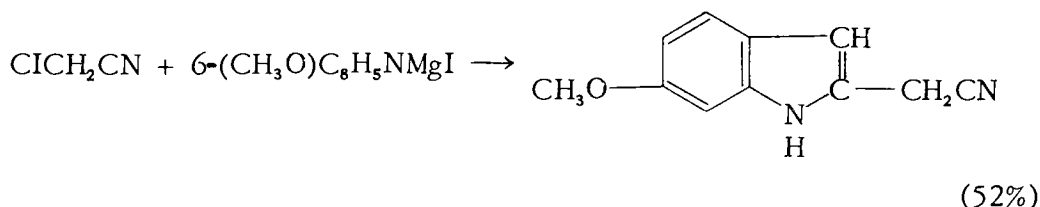
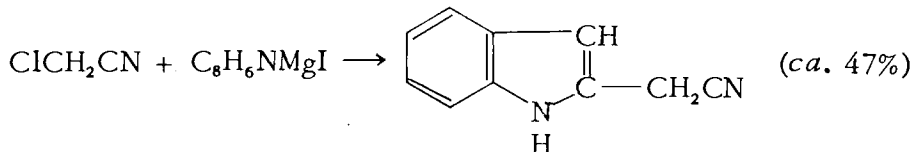
The reports that alkanes are evolved when aliphatic Grignard reagents react with chloroacetonitrile (Mathus, *loc. cit.*⁵²), and that the principle products of the reactions of Grignard reagents with chloroacetonitrile are always polymers, resins, or tars (Mathus, *loc. cit.*,⁵² Tröger and Beck⁵⁴) are indicative that reaction 2 takes place. Perhaps the occurrence of crotononitrile and crotononitrile polymers among the products of reaction of ethylmagnesium bromide with α -chlorobutyronitrile (de Boosere, *loc. cit.*⁵³) might also be so interpreted.



Evidence of the occurrence of reaction 3 is found in the Grignard and Barbier reactions of iodoacetonitrile, which acts as a fairly good iodinating agent.⁵⁵



Except for the indolyl Grignard reagents,⁵⁶ which are singularly unreactive toward cyano groups, evidence for the occurrence of reaction 4 is lacking.



Possibly these are simple alkyl halide replacement reactions, which the corresponding α -halo ketone reactions are not (see α -Halo Ketones and Aldehydes, Chapter VI).

CYANOGEN

The reaction of cyanogen with a Grignard reagent was first investigated by Blaise,⁵⁷ who, using an excess of Grignard reagent, obtained a

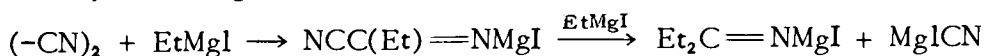
⁵⁴ Tröger and Beck, *J. prakt. Chem.*, [2], 87, 289-311 (1911).

⁵⁵ von Braun, Deutsch, and Schmatloch, *Ber.*, 45, 1246-63 (1912).

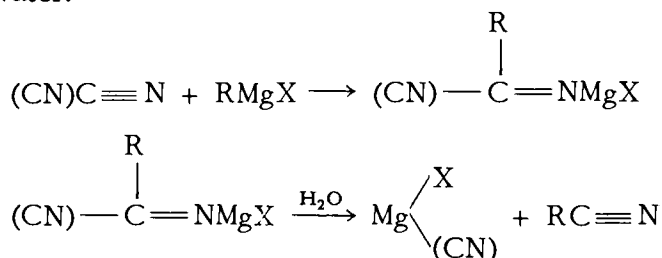
⁵⁶ Majima and Hoshino, *Ber.*, 58B, 2042-6 (1925); Akabori and Saito, *ibid.*, 63B, 2245-8 (1930).

⁵⁷ Blaise, *Compt. rend.*, 132, 38 (1901); *J. Chem. Soc.*, 80, 1, 133 (1901); *Chem. Zentr.*, 1901, I, 298.

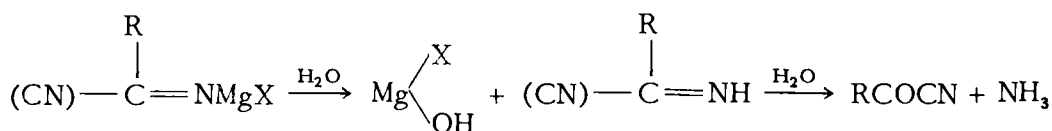
ketone. Blaise represented the reaction as a "normal" addition, followed by a cleavage reaction.



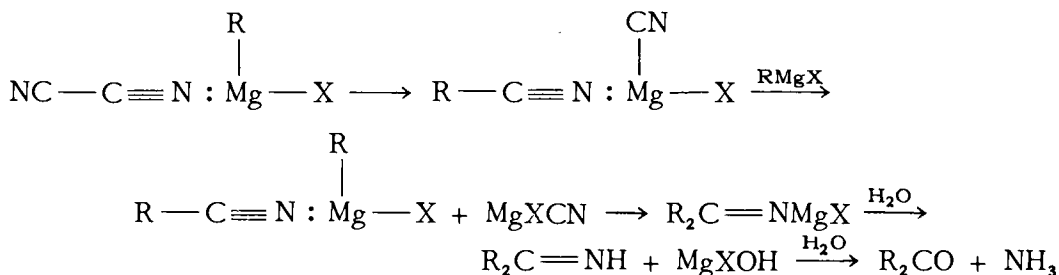
Grignard⁵⁸ showed that, when the amount of Grignard reagent is limited to one equivalent and reverse addition is employed, the major product is a nitrile. Grignard also assumed that the first step in the reaction is a "normal" addition, and postulated rearrangement and cleavage in the presence of water.



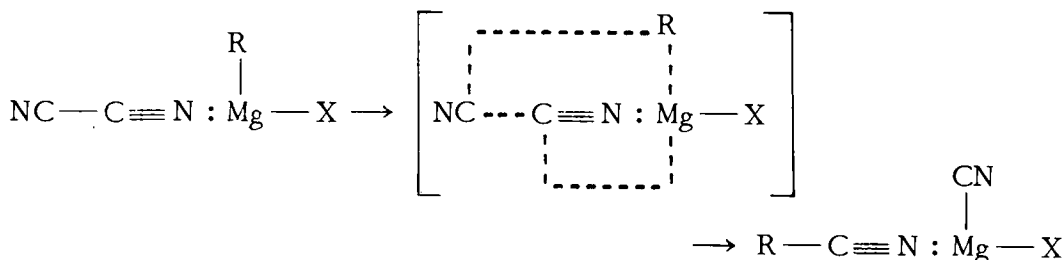
He raised, but did not answer the questions, what part water might play in this process, and why the seemingly more probably hydrolytic reaction does not take place.



On the whole, it appears more probable that the initial reaction involves cleavage and rearrangement, and that ketone formation is attributable to reaction of excess Grignard reagent with the initial product (nitrile complex).



However, in the case of cyanogen there would be no means of distinguishing between a pseudo-addition accompanied by cleavage and rearrangement and a true cleavage reaction.

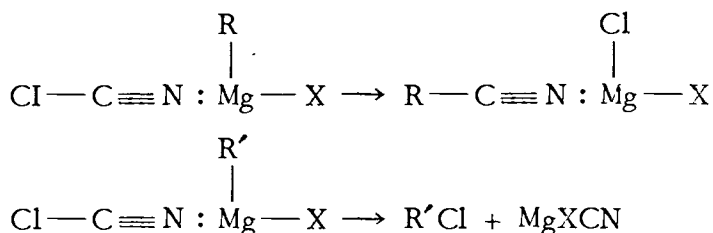


⁵⁸Grignard, Bellet, and Courtot, *Ann. chim.*, [9], 12, 364-93 (1919).

Indeed, in view of the behavior of cyanogen chloride (*q.v.*), it is conceivable that some Grignard reagents might follow one path and some the other.

CYANOGEN HALIDES

With aromatic Grignard reagents (*i.e.*, with Grignard reagents that are relatively reactive toward nitriles in general), cyanogen chloride reacts to yield nitriles (or ketones) as the major products, with traces or very small amounts of chlorides.⁵⁹ Phenethylmagnesium bromide, the only reported reagent that may be taken as reasonably representative of the primary aliphatic Grignard reagents, is also said to give a fair yield (63 per cent) of nitrile. The cycloalkyl and secondary alkyl Grignard reagents, on the other hand, yield the chlorides predominantly, with a little of the nitriles as byproducts.⁶⁰ This suggests a pseudo-addition for the more reactive Grignard reagents and a true cleavage reaction for the less reactive.



Exceptions to the implied generalization that the Grignard reagents more reactive toward nitriles in general react with cyanogen chloride to yield nitriles, whereas the less reactive Grignard reagents yield chlorides are found in the indolylmagnesium halides,⁶¹ and the phenylethynylmagnesium halides (Grignard *et al.*, *loc. cit.*⁶⁰). Although these reagents are extremely unreactive toward nitriles in general, they react with cyanogen chloride to yield the nitriles. However, in view of the differences between the ordinary Grignard reagents, on the one hand, and those derived from the nitrogen heterocycles (*q.v.*, Chapter II) and from the acetylenes, on the other, it is altogether possible that the latter react by a mechanism different from either of those here suggested.

Both cyanogen bromide and cyanogen iodide are predominantly halogenating agents, although the former sometimes yields a little nitrile (and/or ketone) as a byproduct.^{60,62}

⁵⁹ Grignard, *Compt. rend.*, 152, 388-90 (1911); *Chem. Abstr.*, 5, 1589 (1911); Grignard, Bellet, and Courtot, *Ann. chim.*, [9], 4, 28-57 (1915); Willemart, *ibid.*, [10], 12, 345-423 (1929).

⁶⁰ Grignard and Bellet, *Compt. rend.*, 158, 457-61 (1914); *Chem. Abstr.*, 8, 1565 (1914); Grignard and Kashichi Ono, *Bull. soc. chim.*, [4], 39, 1589-94 (1926); Grignard, Bellet, and Courtot, *loc. cit.*⁵⁸

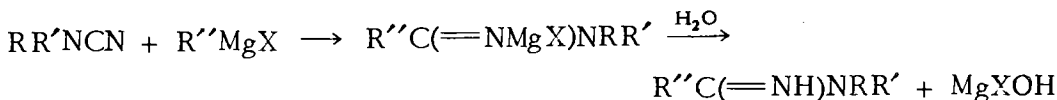
⁶¹ Majima, Shigematsu, and Rokkaku, *Ber.*, 57B, 1453-6 (1924).

⁶² Grignard and Courtot, *Bull. soc. chim.*, [4], 17, 228-31 (1915); Grignard and Perrichon, *Ann. chim.*, [10], 5, 5-36 (1926).

According to Coleman and Leeper,⁶³ di-*n*-butylmagnesium reacts with cyanogen chloride to yield somewhat less nitrile and somewhat more chloride than does *n*-butylmagnesium bromide.

CYANAMIDES

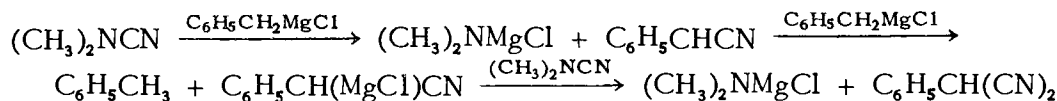
The reactions of cyanamides with Grignard reagents have been little studied. The "normal" reaction is amidine formation.



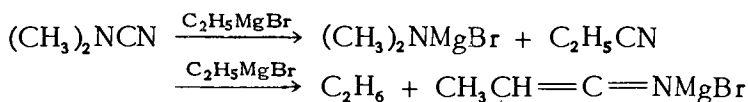
Busch and Hobein⁶⁴ obtained very poor yields of amidines from phenylcyanamide (carbanilinonitrile) and phenyl- and α -naphthylmagnesium bromides, employing a procedure which was perhaps not too well-adapted to the isolation of amidines.

Good yields of amidine hydrochlorides are reported by Adams and Beebe⁶⁵ as resulting from the treatment of dibenzylcyanamide with ethyl-, phenyl-, and *p*-tolylmagnesium bromides.

Vuylsteke⁶⁶ obtained the amidine, in unspecified yield, from dimethylcyanamide and phenylmagnesium bromide. Benzylmagnesium chloride yielded very little amidine, together with dimethylamine, toluene, and phenylmalononitrile. Vuylsteke accounted for the latter products by successive cleavage and condensation reactions.



Ethylmagnesium bromide yielded no isolable product other than ethane. Vuylsteke suggests:



On the basis of the very limited data available one might hazard the prediction that, with proper experimental procedure, the amidines of aromatic acids are probably preparable in satisfactory yields by this method, but that those of aliphatic acids are not.

⁶³ Coleman and Leeper, *Proc. Iowa Acad. Sci.*, 47, 201-5 (1940); *Chem. Abstr.*, 35, 7374 (1941).

⁶⁴ Busch and Hobein, *Ber.*, 40, 4296-8 (1907).

⁶⁵ Adams and Beebe, *J. Am. Chem. Soc.*, 38, 2768-72 (1916).

⁶⁶ Vuylsteke, *Bull. acad. roy. Belg., Classe sci.*, [5], 12, 534-44 (1926); *Chem. Zentr.*, 1927, I, 888.

TABLE X-I
REACTIONS OF GRIGNARD REAGENTS WITH CYANO COMPOUNDS

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CNBr			
BrCN	$(\equiv \text{CMgBr})_2$	$(\equiv \text{CBr})_2$	177; <i>cf.</i> 178
BrCN (7.5 g.)	$\text{C}_2\text{H}_5\text{MgBr}$ (15.5 g. $\text{C}_2\text{H}_5\text{I}$)	$(\text{C}_2\text{H}_5\text{CN})_3$	179
BrCN (0.75 mole)	$\text{C}_6\text{H}_5\text{MgBr}$ (1.0 mole)	$\text{C}_6\text{H}_5\text{Br}$ (80%); $\text{C}_6\text{H}_5\text{CN}$ (trace); $(\text{C}_6\text{H}_5)_2\text{CO}$ (5%)	180, 181, 182
BrCN (sl. excess)	$\text{RC} \equiv \text{CMgBr}^*$	$\text{RC} \equiv \text{CBr}$ (72–78%)	183
BrCN	$\text{C}_6\text{H}_5\text{C} \equiv \text{CMgBr}$	$\text{C}_6\text{H}_5\text{C} \equiv \text{CBr}$ (80%); $\text{C}_6\text{H}_5\text{C} \equiv \text{CCN}$ (trace)	182
BrCN	$\text{R}'\text{C} \equiv \text{CMgBr}^\dagger$	$\text{R}'\text{C} \equiv \text{CBr}$ (64–68%)	183
BrCN	1-Indenyl-MgBr	1-Bromoindene	181, 182
BrCN	$1-\text{C}_{10}\text{H}_7\text{C} \equiv \text{CMgBr}$	$1-\text{C}_{10}\text{H}_7\text{C} \equiv \text{CBr}$ (not isolable)	183
CNCl			
ClCN (7.5 g.)	<i>i</i> - $\text{C}_3\text{H}_7\text{MgBr}$ (0.1 mole)	<i>i</i> - $\text{C}_3\text{H}_7\text{CN}$ (9%); <i>i</i> - $\text{C}_3\text{H}_7\text{Cl}$ (67%)	186
ClCN	<i>n</i> - $\text{C}_4\text{H}_9\text{MgBr}$	More <i>n</i> - $\text{C}_4\text{H}_9\text{CN}$ and less <i>n</i> - $\text{C}_4\text{H}_9\text{Cl}$ than for $(n-\text{C}_4\text{H}_9)_2\text{Mg}$	188
ClCN	$(n-\text{C}_4\text{H}_9)_2\text{Mg}$	Less <i>n</i> - $\text{C}_4\text{H}_9\text{CN}$ and more <i>n</i> - $\text{C}_4\text{H}_9\text{Cl}$ than for <i>n</i> - $\text{C}_4\text{H}_9\text{MgBr}$	188
ClCN	Cyclopentadienyl-MgBr	$(\text{C}_5\text{H}_5\text{CN})_2$	182, 184
ClCN	$(\text{C}_2\text{H}_5)_2\text{CHMgBr}$	$(\text{C}_2\text{H}_5)_2\text{CHCN}$ (8%); $(\text{C}_2\text{H}_5)_2\text{CHCl}$ (70%)	186
ClCN	$\text{C}_6\text{H}_5\text{MgBr}$	$\text{C}_6\text{H}_5\text{CN}$ (80%); $\text{C}_6\text{H}_5\text{Cl}$ (4%)	180, 182
ClCN	$\text{C}_6\text{H}_5\text{MgBr}$ (2.5 equiv.)	$(\text{C}_6\text{H}_5)_2\text{C} = \text{NH} \cdot \text{HCl}$ (equiv. to 80% ketone)	187
ClCN	$\text{C}_6\text{H}_5\text{MgBr}$	" <i>sym</i> -Phenyldichlorotriazine" \downarrow	189
ClCN (8 g.)	$\text{C}_6\text{H}_5\text{MgBr}$ (0.125 mole) + 2,4- $(\text{CH}_3)_2\text{C}_6\text{H}_3\text{MgBr}$ (0.167 mole)	$\text{C}_6\text{H}_5[2,4-(\text{CH}_3)_2\text{C}_6\text{H}_3]\text{C} = \text{NH} \cdot \text{HCl}$ (equiv. to 55% ketone)	187

* R = *n*- C_3H_7 , *n*- C_5H_{11} , $(\text{CH}_2)_5\text{CH}$, *n*- C_9H_{19} .

\dagger R' = $\text{C}_6\text{H}_5\text{CH}_2$, 4- $\text{CH}_3\text{C}_6\text{H}_4$, "*p*-cresyl," $\text{C}_6\text{H}_5\text{CH}_2\text{CH}_2$, 2,4- $(\text{CH}_3)_2\text{C}_6\text{H}_3$.

\ddagger With less Et_2O the product was "diphenylchlorotriazine."

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CNCl (cont.)			
CICN	C ₆ H ₅ MgBr + 1-C ₁₀ H ₇ MgBr	C ₆ H ₅ (1-C ₁₀ H ₇)C≡NH·HCl (equiv. to 55% ketone)	187
CICN	(CH ₂) ₅ CHMgBr	(CH ₂) ₅ CHCN (<i>ca.</i> 5%); (CH ₂) ₅ CHCl (60%)	182
CICN	2-CH ₃ C ₆ H ₄ MgBr	2-CH ₃ C ₆ H ₄ CN (50%)	182
CICN	2-CH ₃ C ₆ H ₄ MgBr (3 equiv. C ₇ H ₇ Br)	(2-CH ₃ C ₆ H ₄) ₂ C≡NH·HCl (equiv. to 73% ketone)	187
CICN	3-CH ₃ C ₆ H ₄ MgBr	3-CH ₃ C ₆ H ₄ CN (60%)	182
CICN	4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ CN (60%)	182
CICN	4-CH ₃ C ₆ H ₄ MgBr (3 equiv. C ₇ H ₇ Br)	(4-CH ₃ C ₆ H ₄) ₂ C≡N·HCl (equiv. to 80% ketone)	187
CICN	4-CH ₃ OC ₆ H ₄ MgBr	4-CH ₃ OC ₆ H ₄ CN (58%); 4-CH ₃ OC ₆ H ₄ Cl ("a little")	180,182
CICN	<i>n</i> -C ₅ H ₁₁ C≡CMgBr	<i>n</i> -C ₅ H ₁₁ C≡CCN (67%)	181,182
CICN	C ₆ H ₅ C≡CMgBr	C ₆ H ₅ C≡CCN (61%); C ₆ H ₅ C≡CCl (trace)	181,182
CICN (7 g.)	Indolyl·MgI (13.3 g. indole)	3-Cyanoindole	190
CICN	C ₆ H ₅ (CH ₂) ₂ MgBr	C ₆ H ₅ (CH ₂) ₂ CN (63%)	180,182
CICN	CH ₃ (C ₆ H ₅)CHMgBr	CH ₃ (C ₆ H ₅)CHCN (10%); CH ₃ (C ₆ H ₅)CHCl (47%)	186
CICN	2,4-(CH ₃) ₂ C ₆ H ₃ MgBr	2,4-(CH ₃) ₂ C ₆ H ₃ CN (40%); 2,4-(CH ₃) ₂ C ₆ H ₃ Cl ("a little"); 1,3-(CH ₃) ₂ C ₆ H ₄ (30%)	182
CICN	2,4-(CH ₃) ₂ C ₆ H ₃ MgBr (0.167 mole) + C ₆ H ₅ MgBr (0.125 mole)	C ₆ H ₅ [2,4-(CH ₃) ₂ C ₆ H ₃]C≡NH·HCl (equiv. to 55% ketone)	187
CICN	2,5-(CH ₃ O) ₂ C ₆ H ₃ MgBr	2,5-(CH ₃ O) ₂ C ₆ H ₃ CN (90%)	182
CICN	(CH ₂) ₅ CHC≡CMgBr	(CH ₂) ₅ CHC≡CCN (67%)*	183
CICN	<i>p</i> -Cresyl·C≡CMgBr	<i>p</i> -Cresyl·C≡CCN*	183
CICN	2-Methylindolyl·MgI	2-Methyl-3-cyanoindole	190

* Ketone was also formed when excess Grignard reagent was used.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CNCl (cont.)			
CICN	$\text{C}_2\text{H}_5(\text{C}_6\text{H}_5)\text{CHMgBr}$	$\text{C}_2\text{H}_5(\text{C}_6\text{H}_5)\text{CHCN}$ (8%); $\text{C}_2\text{H}_5(\text{C}_6\text{H}_5)\text{CHCl}$ (42%)	186
CICN	$2,4,6-(\text{CH}_3)_3\text{C}_6\text{H}_2\text{MgBr}$	$2,4,6-(\text{CH}_3)_3\text{C}_6\text{H}_2\text{CN}$ (40%); $2,4,6-(\text{CH}_3)_3\text{C}_6\text{H}_2\text{Cl}$ (15%); $1,3,5-(\text{CH}_3)_3\text{C}_6\text{H}_3$ (20%)	182
CICN	$(n\text{-C}_4\text{H}_9)_2\text{CHMgBr}$	$(n\text{-C}_4\text{H}_9)_2\text{CHCN}$ ('a little'); $(n\text{-C}_4\text{H}_9)_2\text{CHCl}$ (68%)	186
CICN	$1\text{-C}_{10}\text{H}_7\text{MgBr}$	$1\text{-C}_{10}\text{H}_7\text{CN}$ (65%); $1\text{-C}_{10}\text{H}_7\text{Cl}$	180,182
CICN	$1\text{-C}_{10}\text{H}_7\text{MgBr}$ (3 equiv. $\text{C}_{10}\text{H}_7\text{Br}$)	$(1\text{-C}_{10}\text{H}_7)_2\text{C}=\text{NH} \cdot \text{HCl}$ (equiv. to 55% ketone)	187
CICN (11.8 g.)	$1\text{-C}_{10}\text{H}_7\text{MgBr}$ (95 g. $\text{C}_{10}\text{H}_7\text{Br}$)	After H_2SO_4 hydrolysis: $(1\text{-C}_{10}\text{H}_7)_2\text{CO}$ (58 g., 67%)	185
CICN	$1\text{-C}_{10}\text{H}_7\text{MgBr} + \text{C}_6\text{H}_5\text{MgBr}$	$\text{C}_6\text{H}_5(1\text{-C}_{10}\text{H}_7\text{C}=\text{NH} \cdot \text{HCl})$ (equiv. to 55% ketone)	187
CICN	$m\text{-Xylyl-C}\equiv\text{CMgBr}$	$m\text{-Xylyl-C}\equiv\text{CCN}$ (65-66%)*	183
CICN	$n\text{-C}_8\text{H}_{17}\text{C}\equiv\text{CMgBr}$	$n\text{-C}_8\text{H}_{17}\text{C}\equiv\text{CCN}$ (70%)*	183
CICN	$2\text{-CH}_3\text{-4-CH}_3\text{O-5-}i\text{-C}_3\text{H}_7\text{C}_6\text{H}_2\text{MgBr}$	$2\text{-CH}_3\text{-4-CH}_3\text{O-5-}i\text{-C}_3\text{H}_7\text{C}_6\text{H}_3\text{CN}$ (55%)	182
CICN	$(\text{C}_6\text{H}_5)_2\text{CHMgBr}$	$(\text{C}_6\text{H}_5)_2\text{CHCN}$ (8%); $(\text{C}_6\text{H}_5)_2\text{CHCl}$ (42%); $[(\text{C}_6\text{H}_5)_2\text{CH-}]_2$ (5%)	186
CNI			
ICN (53 g.)	$\text{C}_6\text{H}_5\text{MgBr}$ (0.5 mole)	$\text{C}_6\text{H}_5\text{I}$ (64%); unchanged ICN	180,182
C_2NF_3			
F_3CCN (0.5 mole F_3CCONH_2)	$\text{C}_6\text{H}_5\text{CH}_2\text{MgCl}$ (0.63 mole $\text{C}_7\text{H}_7\text{Cl}$)	$\text{F}_3\text{CCOCH}_2\text{C}_6\text{H}_5$ (36 g., 38.4%)	192

* Ketone was also formed when excess Grignard reagent was used.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂N₂			
(-CN) ₂	(≡CMgBr) ₂	HC≡CH	181,187
(-CN) ₂	C ₂ H ₅ MgI	(C ₂ H ₅) ₂ CO	1
(-CN) ₂	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₅ H ₁₁ CN (62%)	180,187
(-CN) ₂	C ₆ H ₅ MgBr	C ₆ H ₅ CN (75%)	180,187
(-CN) ₂	(CH ₂) ₅ CHMgBr	(CH ₂) ₅ CHCN (50%)	187,191
(-CN) ₂	2-Methylcyclohexyl-MgBr	1-Cyano-2-methylcyclohexane (40%)	187,191
(-CN) ₂	3-Methylcyclohexyl-MgCl	<i>cis</i> - and <i>trans</i> -1-Cyano-3-methylcyclohexane	2,13
(-CN) ₂	3-Methylcyclohexyl-MgBr	1-Cyano-3-methylcyclohexane (60%)	187,191
(-CN) ₂	4-Methylcyclohexyl-MgBr	1-Cyano-4-methylcyclohexane (40%)	187,191
(-CN) ₂	C ₆ H ₅ C≡CMgBr	C ₆ H ₅ C≡CCN (<i>ca.</i> 60%)	187
(-CN) ₂	C ₆ H ₅ (CH ₂) ₃ MgBr	C ₆ H ₅ (CH ₂) ₃ CN (65-70%)	180,187
(-CN) ₂	C ₁₀ H ₁₇ MgCl*	C ₁₀ H ₁₇ CN, m.p. 155-158° (35%); camphane (35%); bicamphanyl; C ₂ H ₅ CN†	187
C₂H₂NCI			
ClCH ₂ CN	RMgX‡	RH; "polymer"	3
ClCH ₂ CN	C ₆ H ₅ MgBr	Black resin	4
ClCH ₂ CN (75 g.)	C ₆ H ₅ MgBr (195 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH ₂ OH; C ₆ H ₅ COCH ₂ Cl (1.5%); (C ₆ H ₅ -) ₂ ; tar	3
ClCH ₂ CN	C ₆ H ₅ MgBr (2 equiv.)	"Polymer"	3
ClCH ₂ CN	Indolyl-MgI	3-Indolylacetonitrile (47-51%)	11
ClCH ₂ CN (6.1 g.)	6-Methoxyindolyl-MgI (11.7 g. 6-methoxyindole)	6-Methoxy-3-indolylacetonitrile (7.4 g., 52%)	194

* From "pinene hydrochloride."

† From C₂H₅MgBr used as activator in Grignard reagent preparation.

‡ R is aliphatic.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₂NI			
ICH ₂ CN	C ₆ H ₅ MgBr	C ₆ H ₅ I (60%)	5
ICH ₂ CN	Br(CH ₂) ₃ CHBrCHBrCH ₃ + Mg	I(CH ₂) ₃ CH=CHCH ₃ (50%)	5
ICH ₂ CN	Br(CH ₂) ₅ CHBrCH ₂ Br + Mg	I(CH ₂) ₅ CH=CH ₂ (65%)	5
ICH ₂ CN	C ₆ H ₅ (CH ₂) ₃ MgBr	C ₆ H ₅ (CH ₂) ₃ I (65%)	5
C₂H₃N			
CH ₃ CN	RMgBr*	CH ₃ C(=NH)CH ₂ CN; CH ₃ COCH ₂ CN; 2,4-dimethyl-3-cyano-6-hydroxypyridine (principal product); 2,4-dimethyl-3- cyano-6-aminopyridine; RH	6
CH ₃ CN	C ₂ H ₅ MgBr	CH ₃ CONH ₂ ; C ₂ H ₆	7
CH ₃ CN	Thiophthenyl-Mgl [†]	Methyl thiophthenyl ketone [†]	14
CH ₃ CN	<i>n</i> -C ₅ H ₁₁ MgBr (1.1 equiv.)	CH ₃ CO- <i>n</i> -C ₅ H ₁₁ (14%) cond'n prod. (40%)	60
CH ₃ CN (49 g., 1.2 mole)	CH ₃ O(CH ₂) ₄ MgCl (159 g., 1.2 mole C ₃ H ₁₁ ClO)	CH ₃ CO(CH ₂) ₄ OCH ₃ (35 g., 22.5%)	232
CH ₃ CN	C ₆ H ₅ MgBr (1.2 equiv.)	CH ₃ COC ₆ H ₅ (45%); 2,4-dimethyl-3-cyano- 6-aminopyridine	8
CH ₃ CN (0.25 mole)	C ₆ H ₅ MgBr (160 g. C ₆ H ₅ Br)	CH ₃ COC ₆ H ₅ (21 g., 70%)	9,4
CH ₃ CN	C ₆ H ₅ MgBr (1.1 equiv.)	CH ₃ COC ₆ H ₅ (33%)	59
CH ₃ CN	C ₆ H ₅ MgBr (3.0 equiv.)	CH ₃ COC ₆ H ₅ (70%)	59
CH ₃ CN	C ₆ H ₅ MgBr (1.1 equiv.)	CH ₃ COC ₆ H ₅ (37%); cond'n prod. (ca. 50%)	60
CH ₃ CN (0.25 mole)	<i>n</i> -C ₄ H ₉ C≡CMgBr (21 g. <i>n</i> -C ₄ H ₉ C≡CH)	<i>n</i> -C ₄ H ₉ C≡CH (19.5 g.)	195
CH ₃ CN	C ₆ H ₅ CH ₂ MgCl	CH ₃ COCH ₂ C ₆ H ₅ (15.8%); C ₇ H ₈	10
CH ₃ CN (0.25 mole)	C ₆ H ₅ C≡CMgBr (0.25 mole)	C ₆ H ₅ C≡CH (20 g.)	195

* R = CH₃, C₂H₅.

[†] Orientation unknown.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₃N (<i>cont.</i>)			
CH ₃ CN	Indolyl-MgBr	Recovered CH ₃ CN (<i>ca.</i> 100%)	11
CH ₃ CN	2,5-(CH ₃) ₂ C ₆ H ₃ MgBr	CH ₃ COC ₆ H ₃ -2,5-(CH ₃) ₂ ("poor yield")	198
CH ₃ CN	1-C ₁₀ H ₇ MgBr	1-CH ₃ COC ₁₀ H ₇	15
CH ₃ CN (5 g.)	ω -Camphenyl-MgBr (21.5 g.)	ω -Acetylcamphene* (3.8 g., 10.7%)	12
C₂H₃NO			
HOCH ₂ CN (0.1 mole)	CH ₃ MgI (1 equiv.) + (CH ₂) ₄ CHMgCl (1 equiv.)	CH ₄ ; HOCH ₂ COCH(CH ₂) ₄ (isolated as 3,5-dinitrobenzoate; 3.8 g.)	16
HOCH ₂ CN (0.1 mole)	CH ₃ MgI (1 equiv.) + 2-Methylcyclopentyl-MgCl (1 equiv.)	CH ₄ ; hydroxymethyl 2-methylcyclopentyl ketone (isolated as 3,5-dinitrobenzoate)	16
HOCH ₂ CN (4.0 ml.)	CH ₃ MgI (4.8 ml. CH ₃ I) + (CH ₂) ₅ CHMgCl (9.2 ml. C ₆ H ₁₁ Cl)	CH ₄ ; HOCH ₂ COCH(CH ₂) ₅ (isolated as 3,5-dinitrobenzoate; 7.8 g., crude)	16
HOCH ₂ CN	C ₆ H ₅ CH ₂ MgCl	HOCH ₂ COCH ₂ C ₆ H ₅ ; HOCH ₂ C(CH ₂ C ₆ H ₅) ₂ OH	196
C₃H₂N₂			
H ₂ C(CN) ₂ (6.6 g.)	C ₆ H ₅ MgBr (6.1 g. Mg)	Recovered H ₂ C(CN) ₂ (6.1 g.)	17
C₃H₅N			
C ₂ H ₅ CN	CH ₃ MgI (1 equiv.) + C ₆ H ₅ MgBr (1 equiv.)	C ₂ H ₅ COC ₆ H ₅	18
C ₂ H ₅ CN	CH ₃ MgI (1 equiv.) + C ₆ H ₅ CH ₂ MgCl (1 equiv.)	C ₂ H ₅ COCH ₃ ; C ₂ H ₅ COCH ₂ C ₆ H ₅	18
C ₂ H ₅ CN	CH ₃ MgI (1 equiv.)	C ₂ H ₅ COCH ₃ (21%); C ₂ H ₅ (C ₂ H ₅ CO)CHCN (28%)	60
C ₂ H ₅ CN	C ₂ H ₅ MgBr (sl. excess)	(C ₂ H ₅ CN) ₃ (<i>ca.</i> 8-10%); (C ₂ H ₅) ₂ CO (<i>ca.</i> 35%); C ₂ H ₆ (5.9 l. per mole nitrile); (C ₂ H ₅) ₃ COH ("small am't"); (C ₂ H ₅ CN) ₂ (<i>ca.</i> 20-25%)	19

* The corresponding ket mine l c l r i e v e f 1 °.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₅N (<i>cont.</i>)			
C ₂ H ₅ CN	C ₂ H ₅ MgBr (1.1 equiv.)	(C ₂ H ₅) ₂ CO (23%)	59
C ₂ H ₅ CN	<i>t</i> -C ₄ H ₉ MgCl (1.1 equiv.)	C ₂ H ₅ CO- <i>t</i> -C ₄ H ₉ (5%); C ₂ H ₅ (C ₂ H ₅ CO)CHCN (20%)	60
C ₂ H ₅ CN (61 g., 1.1 mole)	CH ₃ O(CH ₂) ₃ MgCl (147 g., 1.36 mole C ₄ H ₉ ClO)	C ₂ H ₅ CO(CH ₂) ₃ OCH ₃ (76 g., 54%)	232
C ₂ H ₅ CN	<i>n</i> -C ₅ H ₁₁ MgBr (1.1 equiv.)	C ₂ H ₅ CO- <i>n</i> -C ₅ H ₁₁ (61%); cond'n prod. (<i>ca.</i> 5%)	60
C ₂ H ₅ CN	CH ₂ (CH ₂ CH ₂ MgCl) ₂	C ₂ H ₅ CO- <i>n</i> -C ₅ H ₁₁ (60%); H ₂ C(CH ₂ CH ₂ COC ₂ H ₅) ₂ (20%)	20
C ₂ H ₅ CN	C ₆ H ₅ MgBr (excess)	C ₂ H ₅ COC ₆ H ₅ (<i>ca.</i> 80%); recovered C ₂ H ₅ CN (4-5%)	8
C ₂ H ₅ CN (0.25 mole)	C ₆ H ₅ MgBr (160 g. C ₆ H ₅ Br)	C ₂ H ₅ COC ₆ H ₅ (31 g., 91%)	9
C ₂ H ₅ CN	C ₆ H ₅ MgBr (1.1 equiv.)	C ₂ H ₅ COC ₆ H ₅ (83%)	59,60
C ₂ H ₅ CN	C ₆ H ₅ MgBr (3.0 equiv.)	C ₂ H ₅ COC ₆ H ₅ (91%)	59
C₃H₅NO			
CH ₃ OCH ₂ CN (142 g., 2 moles)	C ₂ H ₅ MgBr (372 g., 3 moles C ₂ H ₅ Br)	CH ₃ OCH ₂ COC ₂ H ₅ (120 g., 59%)	232
CH ₃ OCH ₂ CN (35 g.)	C ₂ H ₅ MgI (1.5 equiv.)	CH ₃ OCH ₂ COC ₂ H ₅ (35 g., 70%)	21
CH ₃ OCH ₂ CN	RMgX*	CH ₃ OCH ₂ COR	197
CH ₃ OCH ₂ CN	H ₂ C=CHCH ₂ MgBr (2 equiv.)	CH ₃ OCH ₂ (H ₂ C=CHCH ₂) ₂ CNH ₂ (65.6%)	22
CH ₃ OCH ₂ CN (20 g.)	<i>n</i> -C ₃ H ₇ MgI (60 g. C ₃ H ₇ I)	CH ₃ OCH ₂ CO- <i>n</i> -C ₃ H ₇ (25 g.)	21
CH ₃ OCH ₂ CN (70 g.)	CH ₃ O(CH ₂) ₃ MgI (200 g. C ₄ H ₉ IO)	CH ₃ OCH ₂ CO(CH ₂) ₃ OCH ₃	23
CH ₃ OCH ₂ CN (21.3 g., 0.3 mole)	C ₆ H ₅ MgBr (56.5 g., 0.36 mole C ₆ H ₅ Br)	CH ₃ OCH ₂ COC ₆ H ₅ (32-35 g., 71-78%)	237,238
CH ₃ OCH ₂ CN	C ₆ H ₅ CH ₂ MgCl	CH ₃ OCH ₂ COCH ₂ C ₆ H ₅	196
CH ₃ CH(OH)CN	C ₂ H ₅ MgBr	CH ₃ CH(OH)COC ₂ H ₅	24

* R = C₂H₅, *n*-C₃H₇, *n*-C₄H₉, *i*-C₅H₁₁.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₆N₂			
(CH ₃) ₂ NCN	C ₂ H ₅ MgBr	No product identified	25
(CH ₃) ₂ NCN	C ₆ H ₅ MgBr	(CH ₃) ₂ NC(=NH)C ₆ H ₅	25
(CH ₃) ₂ NCN	C ₆ H ₅ CH ₂ MgCl	(CH ₃) ₂ NH; CH ₃ C ₆ H ₅ ; C ₆ H ₅ CH ₂ C(=NH)N(CH ₃) ₂ (very little); C ₆ H ₅ CH ₂ CN	25
C₄H₂N₂S			
5-Cyanothiazole (30 g.)	CH ₃ O(CH ₂) ₃ MgBr (75 g. C ₄ H ₉ BrO)	5-Thiazolyl 3-methoxypropyl ketone (18 g.)	199
5-Cyanothiazole (11 g.)	C ₆ H ₅ MgBr (30 g. C ₆ H ₅ Br)	5-Benzoylthiazole (15 g.)	199
C₄H₅N			
H ₂ C=CHCH ₂ CN	C ₂ H ₅ MgBr	C ₆ H ₁₀ ; CH ₃ CH=CHCN (2 isomers); (H ₂ C=CHCH ₂ CN) ₂ ; other cond'n products	26
CH ₃ CH=CHCN (low-boiling isomer)	C ₂ H ₅ MgBr (2 equiv.)	(CH ₃ CH=CHCN) ₃ (ca. 60%); (C ₂ H ₅) ₂ C(OH)CH=CHCH ₃ ("small yield")	27
(CH ₂) ₂ CHCN	CH ₃ MgBr	(CH ₂) ₂ CHCOCH ₃	28,29
(CH ₂) ₂ CHCN	C ₂ H ₅ MgBr	(CH ₂) ₂ CHCOC ₂ H ₅	28,29
(CH ₂) ₂ CHCN	<i>n</i> -C ₃ H ₇ MgBr	(CH ₂) ₂ CHCO- <i>n</i> -C ₃ H ₇	29
(CH ₂) ₂ CHCN	<i>i</i> -C ₃ H ₇ MgBr	(CH ₂) ₂ CHCO- <i>i</i> -C ₃ H ₇	28,29
(CH ₂) ₂ CHCN	(CH ₂) ₂ CHCH ₂ MgBr	(CH ₂) ₂ CHCOCH ₂ CH(CH ₂) ₂	30
(CH ₂) ₂ CHCN	<i>n</i> -C ₄ H ₉ MgBr	(CH ₂) ₂ CHCO- <i>n</i> -C ₄ H ₉	29
(CH ₂) ₂ CHCN	<i>i</i> -C ₄ H ₉ MgBr	(CH ₂) ₂ CHCO- <i>i</i> -C ₄ H ₉	29
(CH ₂) ₂ CHCN	<i>n</i> -C ₅ H ₁₁ MgBr	(CH ₂) ₂ CHCO- <i>n</i> -C ₅ H ₁₁	29
(CH ₂) ₂ CHCN	<i>i</i> -C ₅ H ₁₁ MgBr	(CH ₂) ₂ CHCO- <i>i</i> -C ₅ H ₁₁	30
(CH ₂) ₂ CHCN	C ₆ H ₅ MgBr (sl. excess)	(CH ₂) ₂ CHCOC ₆ H ₅ (85%)	31,8,29

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₅N (<i>cont.</i>)			
(CH ₂) ₂ CHCN (26.8 g.)	C ₆ H ₅ MgBr (94.2 g. C ₆ H ₅ Br)	(CH ₂) ₂ CHC(=NH)C ₆ H ₅ (isolated as hydrochloride)	32,8
(CH ₂) ₂ CHCN	<i>i</i> -C ₆ H ₁₃ MgBr	(CH ₂) ₂ CHCO- <i>i</i> -C ₆ H ₁₃	30
(CH ₂) ₂ CHCN	C ₆ H ₅ CH ₂ MgCl	(CH ₂) ₂ CHCOCH ₂ C ₆ H ₅	29
(CH ₂) ₂ CHCN (15 g.)	2-CH ₃ C ₆ H ₄ MgBr (32 g. C ₇ H ₇ Br)	(CH ₂) ₂ CHC(=NH)C ₆ H ₄ -2-CH ₃	33
(CH ₂) ₂ CHCN (5 g.)	3-CH ₃ C ₆ H ₄ MgBr (43 g. C ₇ H ₇ Br)	(CH ₂) ₂ CHC(=NH)C ₆ H ₄ -3-CH ₃	33
(CH ₂) ₂ CHCN (9.75 g.)	4-CH ₃ C ₆ H ₄ MgBr (34.9 g. C ₇ H ₅ Br)	(CH ₂) ₂ CHC(=NH)C ₆ H ₄ -4-CH ₃ (11.7 g., crude)	33
(CH ₂) ₂ CHCN (5 g.)	1-C ₁₀ H ₇ MgBr (52 g. C ₁₀ H ₇ Br)	(CH ₂) ₂ CHC(=NH)-1-C ₁₀ H ₇ ("poor yield")	33
C₄H₅NO₂			
H ₅ C ₂ O ₂ CCN (0.33 mole)	C ₂ H ₅ MgBr (1 mole)	(C ₂ H ₅) ₃ COH (24 g.); C ₂ H ₅ COC(C ₂ H ₅) ₂ OH (17 g.)	35
H ₅ C ₂ O ₂ CCN (6 g.)	C ₆ H ₅ MgBr (34 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ COH (3 g.); (C ₆ H ₅ -) ₂	36
H ₃ CO ₂ CCH ₂ CN (38 g.)	C ₂ H ₅ MgI (156 g. C ₂ H ₅ I)	H ₃ CO ₂ CCH=C(NH ₂)C ₂ H ₅ (22 g.)	200
C₄H₆NBr			
BrCH ₂ CH ₂ CH ₂ CN	C ₂ H ₅ MgBr	<i>n</i> -C ₃ H ₇ COC ₂ H ₅ ; BrCH ₂ CH ₂ CH ₂ COC ₂ H ₅ ; <i>n</i> -C ₅ H ₁₁ COC ₂ H ₅	28
C₄H₆NCI			
ClCH ₂ CH ₂ CH ₂ CN	CH ₃ MgX	2-Methylpyrroline (10-23%)	34
ClCH ₂ CH ₂ CH ₂ CN (1 mole)	C ₂ H ₅ MgBr (1 mole)	C ₂ H ₆ ; (CH ₂) ₂ CHCOC ₂ H ₅ (23-25%); C ₂ H ₅ COCH ₂ CH ₂ CH ₂ Cl (14-17%); other products (1%)	37
ClCH ₂ CH ₂ CH ₂ CN (1 mole)	C ₂ H ₅ MgBr (2 moles)	C ₂ H ₆ ; (CH ₂) ₂ CHCOC ₂ H ₅ (28-30%); C ₂ H ₅ COCH ₂ CH ₂ CH ₂ Cl (27-31%); [(CH ₂) ₂ CHCN] _x ; other products (2%)	37

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₆NCI (<i>cont.</i>)			
ClCH ₂ CH ₂ CH ₂ CN	C ₂ H ₅ MgBr (+ dry HCl)	(CH ₂) ₂ CHC(C ₂ H ₅)=NH·HCl; ClCH ₂ CH ₂ CH ₂ COC ₂ H ₅	37
ClCH ₂ CH ₂ CH ₂ CN	C ₂ H ₅ MgX	2-Ethylpyrroline (38-40%)	34,32
ClCH ₂ CH ₂ CH ₂ CN (15 g.)	C ₂ H ₅ MgBr (38 g. C ₂ H ₅ Br)	2-Ethylpyrroline (46%)	38,39
ClCH ₂ CH ₂ CH ₂ CN	<i>n</i> -C ₃ H ₇ MgX	2- <i>n</i> -Propylpyrroline (51%)	34
ClCH ₂ CH ₂ CH ₂ CN (30 g.)	Pyrryl-MgBr (22 g. C ₄ H ₄ N)	2- <i>α</i> -Pyrrylpyrroline (45%)	43
ClCH ₂ CH ₂ CH ₂ CN (12 g.)	2-Thienyl-MgI (24.3 g. C ₄ H ₃ IS)	2-(2-Thienyl)pyrroline (4.8 g., 27.5%)	41
ClCH ₂ CH ₂ CH ₂ CN	<i>n</i> -C ₄ H ₉ MgX	2- <i>n</i> -Butylpyrroline (66%)	34
ClCH ₂ CH ₂ CH ₂ CN (15 g.)	C ₆ H ₅ MgBr (56 g. C ₆ H ₅ Br)	2-Phenylpyrroline (55%)	38,39,40
ClCH ₂ CH ₂ CH ₂ CN	C ₆ H ₅ MgBr	ClCH ₂ CH ₂ CH ₂ C(=NH)C ₆ H ₅ ; ClCH ₂ CH ₂ CH ₂ COC ₆ H ₅	32
ClCH ₂ CH ₂ CH ₂ CN	(CH ₂) ₅ CHMgX	2-Cyclohexylpyrroline	39
ClCH ₂ CH ₂ CH ₂ CN (15 g.)	C ₆ H ₅ CH ₂ MgCl (45 g. C ₇ H ₇ Cl)	2-Benzylpyrroline (13%)	38,39
ClCH ₂ CH ₂ CH ₂ CN	C ₆ H ₅ CH ₂ MgX	2-Benzylpyrroline (45-67%)	34
ClCH ₂ CH ₂ CH ₂ CN (15.5 g.)	2-CH ₃ C ₆ H ₄ MgBr (34.9 g. C ₇ H ₇ Br)	2- <i>o</i> -Tolylpyrroline (12.6 g.)	33
ClCH ₂ CH ₂ CH ₂ CN (13 g.)	3-CH ₃ C ₆ H ₄ MgBr (34.9 g. C ₇ H ₇ Br)	2- <i>m</i> -Tolylpyrroline (9.8 g.)	33
ClCH ₂ CH ₂ CH ₂ CN (15 g.)	4-CH ₃ C ₆ H ₄ MgBr (51.3 g. C ₇ H ₇ Br)	2- <i>o</i> -Tolylpyrroline (6.3 g.)	33,39
ClCH ₂ CH ₂ CH ₂ CN (10.4 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (24.9 g. C ₉ H ₁₁ Br)	2-Mesitylpyrroline (7.4 g., 39.6%)	41
CH ₃ CHClCH ₂ CN*	C ₂ H ₅ MgBr (1 equiv.)	CH ₃ CH=CHCN (52%); tar (6-7%); CH ₃ CHClCH ₂ COC ₂ H ₅ (2%); polymer (30%); C ₂ H ₆	37
CH ₃ CHClCH ₂ CN*	C ₂ H ₅ MgBr (2 equiv.)	(CH ₃ CH=CHCN) ₃ ; tar (10%); C ₂ H ₆	37
CH ₃ CHClCH ₂ CN†	C ₂ H ₅ MgBr (1 equiv.)	CH ₃ CH=CHCN; tar (40%); C ₂ H ₆ ; hexadiene	37

* Addition of Et₂O-nitrile solution to Grignard solution; 24 hours standing.† Addition of Et₂O-nitrile solution to Grignard solution.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₆NCl (<i>cont.</i>)			
CH ₃ CHClCH ₂ CN*	C ₂ H ₅ MgBr (2 equiv.)	CH ₃ CH=CHCN; tar (20%); C ₂ H ₆ ; 1,1,2-triethylethyleneamine	37
C₄H₇N			
<i>n</i> -C ₃ H ₇ CN	C ₂ H ₅ MgBr (1.2 equiv.)	<i>n</i> -C ₃ H ₇ COC ₂ H ₅ (<i>ca.</i> 40%); <i>n</i> -C ₃ H ₇ (C ₂ H ₅) ₂ COH (<i>ca.</i> 1%); (<i>n</i> -C ₃ H ₇ CN) ₃ (<i>ca.</i> 25%); (<i>n</i> -C ₃ H ₇ CN) ₂ (<i>ca.</i> 8-10%); tar	44
<i>n</i> -C ₃ H ₇ CN (0.33 mole)	C ₆ H ₅ MgBr (0.5 mole)	<i>n</i> -C ₃ H ₇ COC ₆ H ₅ (90%)	8
<i>n</i> -C ₃ H ₇ CN (0.25 mole)	C ₆ H ₅ MgBr (1 mole)	<i>n</i> -C ₃ H ₇ COC ₆ H ₅ (77%)	9
<i>n</i> -C ₃ H ₇ CN	C ₆ H ₅ MgBr (1.1 equiv.)	<i>n</i> -C ₃ H ₇ COC ₆ H ₅ (82%)	59
<i>n</i> -C ₃ H ₇ CN	C ₆ H ₅ MgBr (3.0 equiv.)	<i>n</i> -C ₃ H ₇ COC ₆ H ₅ (77%)	59
<i>n</i> -C ₃ H ₇ CN	C ₆ H ₅ CH ₂ MgCl	<i>n</i> -C ₃ H ₇ COCH ₂ C ₆ H ₅	45
C₄H₇NO			
CH ₃ CH(OCH ₃)CN	CH ₃ MgBr	CH ₃ CH(OCH ₃)COCH ₃ (37%)	42
CH ₃ CH(OCH ₃)CN (24 g.)	CH ₃ MgI (60 g. CH ₃ I)	CH ₃ CH(OCH ₃)COCH ₃ (19 g., 65%)	21
CH ₃ CH(OCH ₃)CN (22.1 g.)	CH ₃ MgI (39 g. CH ₃ I)	CH ₃ CH(OCH ₃)COCH ₃ (12 g., 45%)	48,49
CH ₃ CH(OCH ₃)CN	C ₂ H ₅ MgBr	CH ₃ CH(OCH ₃)COC ₂ H ₅ (22%)	42
CH ₃ CH(OCH ₃)CN (17 g.)	C ₂ H ₅ MgI (50 g. C ₂ H ₅ I)	CH ₃ CH(OCH ₃)COC ₂ H ₅ (17 g.)	21
CH ₃ CH(OCH ₃)CN	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ CH(OCH ₃)CO- <i>n</i> -C ₃ H ₇ (35%)	42
CH ₃ CH(OCH ₃)CN (17 g.)	<i>n</i> -C ₃ H ₇ MgBr (37 g. C ₃ H ₇ Br)	CH ₃ CH(OCH ₃)CO- <i>n</i> -C ₃ H ₇ (19 g., 73%)	201
CH ₃ CH(OCH ₃)CN	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ CH(OCH ₃)CO- <i>i</i> -C ₃ H ₇ (13%)	42
CH ₃ CH(OCH ₃)CN	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ CH(OCH ₃)CO- <i>n</i> -C ₄ H ₉ (63%)	42
CH ₃ CH(OCH ₃)CN	<i>i</i> -C ₄ H ₉ MgBr	CH ₃ CH(OCH ₃)CO- <i>i</i> -C ₄ H ₉ (21%)	42
CH ₃ CH(OCH ₃)CN	<i>s</i> -C ₄ H ₉ MgBr	CH ₃ CH(OCH ₃)CO- <i>s</i> -C ₄ H ₉ (43%)	42

* Addition of Et₂O-nitrile solution to Grignard solution.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₇NO (cont.)			
CH ₃ CH(OCH ₃)CN	<i>t</i> -C ₄ H ₉ MgCl*	CH ₃ CH(OCH ₃)CO- <i>t</i> -C ₄ H ₉ (14%)	42
CH ₃ CH(OCH ₃)CN	<i>n</i> -C ₅ H ₁₁ MgBr	CH ₃ CH(OCH ₃)CO- <i>n</i> -C ₅ H ₁₁ (36%)	42
CH ₃ CH(OCH ₃)CN	<i>i</i> -C ₅ H ₁₁ MgBr	CH ₃ CH(OCH ₃)CO- <i>i</i> -C ₅ H ₁₁ (29%)	42
C ₂ H ₅ OCH ₂ CN (43 g.)	CH ₃ MgI (0.5 mole)	H ₅ C ₂ OCH ₂ COCH ₃ (28 g.)	46,21
C ₂ H ₅ OCH ₂ CN	C ₂ H ₅ MgI	H ₅ C ₂ OCH ₂ COC ₂ H ₅ (70%)	46,47,21
C ₂ H ₅ OCH ₂ CN (100 g.)	H ₂ C=CHCH ₂ MgBr (370 g. C ₃ H ₅ Br)	H ₅ C ₂ OCH ₂ (H ₂ C=CHCH ₂) ₂ CNH ₂ (156.6 g., 78.7%)	22
C ₂ H ₅ OCH ₂ CN (49.5 g.)	H ₂ C=CHCH ₂ MgBr (100 g. C ₃ H ₅ Br) + <i>n</i> -C ₃ H ₇ MgBr (86.3 g. C ₃ H ₇ Br)	H ₂ C=CHCH ₂ (<i>n</i> -C ₃ H ₇)(H ₅ C ₂ OCH ₂)CNH ₂ (60.7%)	22
C ₂ H ₅ OCH ₂ CN	<i>n</i> -C ₃ H ₇ MgBr (2 equiv.)	H ₅ C ₂ OCH ₂ (<i>n</i> -C ₃ H ₇) ₂ CNH ₂ (98.9%)	22
C ₂ H ₅ OCH ₂ CN	<i>n</i> -C ₃ H ₇ MgI (1.5 equiv.)	C ₂ H ₅ OCH ₂ CO- <i>n</i> -C ₃ H ₇	21
C ₂ H ₅ OCH ₂ CN	<i>n</i> -C ₃ H ₇ MgX	C ₂ H ₅ OCH ₂ CO- <i>n</i> -C ₃ H ₇	47
C ₂ H ₅ OCH ₂ CN	<i>n</i> -C ₅ H ₁₁ MgX	C ₂ H ₅ OCH ₂ CO- <i>n</i> -C ₅ H ₁₁	47
C ₂ H ₅ OCH ₂ CN	C ₆ H ₅ MgBr	C ₂ H ₅ OCH ₂ COC ₆ H ₅	46,47,48
C ₂ H ₅ OCH ₂ CN	C ₆ H ₅ CH ₂ MgCl	C ₂ H ₅ OCH ₂ COCH ₂ C ₆ H ₅	196
HO(CH ₃) ₂ CCN	CH ₃ MgI	(CH ₃) ₂ C(OH)COCH ₃	24
HO(CH ₃) ₂ CCN	C ₂ H ₅ MgBr	(CH ₃) ₂ C(OH)COC ₂ H ₅	24
HO(CH ₃) ₂ CCN	C ₂ H ₅ MgBr	<i>t</i> -C ₅ H ₁₁ OH (principal product); (CH ₃) ₂ C(OH)COC ₂ H ₅ (7%)	69
HO(CH ₃) ₂ CCN (43 g.)	C ₆ H ₅ (CH ₃) ₂ CMgCl (155 g. C ₉ H ₁₁ Cl)	HO(CH ₃) ₂ CCOC(CH ₃) ₂ C ₆ H ₅	202
C₄H₈N₂			
(CH ₃) ₂ NCH ₂ CN	CH ₃ MgI (2 equiv.)	(CH ₃) ₂ NC ₂ H ₅ (4%); (CH ₃) ₂ NCH ₂ COCH ₃ (50%)	18
(CH ₃) ₂ NCH ₂ CN	C ₂ H ₅ MgBr (2 equiv.)	(CH ₃) ₂ N- <i>n</i> -C ₃ H ₇ (60%)	18
(CH ₃) ₂ NCH ₂ CN	HC≡CMgBr (2 equiv.)	No reaction	18

* No ketone was obtained with *t*-C₄H₉MgBr or *t*-C₄H₉MgI.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₈N₂ (cont.)			
(CH ₃) ₂ NCH ₂ CN	<i>n</i> -C ₃ H ₇ MgBr (2 equiv.)	(CH ₃) ₂ N- <i>n</i> -C ₄ H ₉ (58%)	18
(CH ₃) ₂ NCHCN	C ₆ H ₅ MgBr (2 equiv.)	(CH ₃) ₂ NCH ₂ COC ₆ H ₅ (78%)	18
(CH ₃) ₂ NCH ₂ CN	C ₆ H ₅ CH ₂ MgCl (2 equiv.)	(CH ₃) ₂ NCH ₂ COCH ₂ C ₆ H ₅ (> 50%)	18
C₅H₃NO			
2-Furonitrile	CH ₃ MgX	2-Acetylfuran	56
2-Furonitrile	C ₂ H ₅ MgX	2-Propionylfuran	56
2-Furonitrile	<i>n</i> -C ₃ H ₇ MgX	2-Butyrylfuran	56
2-Furonitrile	<i>i</i> -C ₄ H ₉ MgX	2-Isovaleryl furan	56
2-Furonitrile	<i>i</i> -C ₅ H ₁₁ MgX	2-Isocaprolylfuran	56
2-Furonitrile	C ₆ H ₅ MgX	2-Benzoylfuran	56
C₅H₃N₂ClO			
3-Methyl-4-chloro-5-cyano- isoxazole (35 g.)	CH ₃ MgI (40 g. CH ₃ I)	3-Methyl-4-chloro-5-acetylisoxazole	203
C₅H₆N₂			
H ₂ C(CH ₂ CN) ₂	RMgX* (1 equiv.)	C ₁₀ H ₁₁ N ₃ O	51,26
H ₂ C(CH ₂ CN) ₂	C ₂ H ₅ MgBr (4 equiv.)	C ₂ H ₅ CO(CH ₂) ₃ CN (?) (small amount); C ₂ H ₆	51,26
H ₂ C(CH ₂ CN) ₂	C ₂ H ₅ MgBr	H ₂ C(CH ₂ COC ₂ H ₅) ₂ (trace)	52
H ₂ C(CH ₂ CN) ₂ (60 g.)	C ₆ H ₅ MgBr (200 g. C ₆ H ₅ Br)	NC(CH ₂) ₃ C(=NH·HBr)C ₆ H ₅ (75 g., crude)	53
H ₂ C(CH ₂ CN) ₂	C ₆ H ₅ CH ₂ MgCl (2 equiv.)	2-Imino-6,6-dibenzylpiperidine	54
(CH ₃) ₂ C(CN) ₂ (6.4 g.)	C ₆ H ₅ MgBr (8.3 g. Mg)	(CH ₃) ₂ C(COC ₆ H ₅) ₂ (4.8 g.); (C ₆ H ₅) ₂ CO (1.3 g.)	17
(CH ₃) ₂ C(CN) ₂ (6 g.)	C ₆ H ₅ MgBr (2 g. Mg)	C ₆ H ₅ CN (5.1 g.); <i>i</i> -C ₃ H ₇ CN (1.1 g.)	17

* R = CH₃, C₂H₅, *n*-C₃H₇.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₇N			
(CH ₃) ₂ C=CHCN (5 g.)	C ₁₀ H ₁₇ MgBr*	Zingiborone (1.2 g.)	58
C₅H₇NO₂			
H ₅ C ₂ O ₂ CCH ₂ CN	C ₂ H ₅ MgBr (4 equiv.)	HO(C ₂ H ₅) ₂ CCH ₂ CN; H ₅ C ₂ O ₂ CCH ₂ COC ₂ H ₅ ; H ₅ C ₂ O ₂ CCH ₂ C(=NH)C ₂ H ₅ ; C ₂ H ₆	55
H ₅ C ₂ O ₂ CCH ₂ CN	C ₂ H ₅ MgI	H ₅ C ₂ O ₂ CCH ₂ COC ₂ H ₅	61, 1
H ₅ C ₂ O ₂ CCH ₂ CN	C ₂ H ₅ MgI	(C ₂ H ₅ CO) ₂ CHC ₂ H ₅ (25-30%)	62
H ₅ C ₂ O ₂ CCH ₂ CN	<i>n</i> -C ₃ H ₇ MgX	H ₅ C ₂ O ₂ CCH ₂ CO- <i>n</i> -C ₃ H ₇	61
H ₅ C ₂ O ₂ CCH ₂ CN	C ₆ H ₅ MgBr	(C ₆ H ₅ CO) ₂ CHC ₂ H ₅ (60%)	62
C₅H₈NCl			
<i>n</i> -C ₃ H ₇ CHClCN (1 mole)	C ₂ H ₅ MgBr (2 moles)	1,1-Diethyl-2- <i>n</i> -propyl ethylenimine (main product); (<i>n</i> -C ₃ H ₇ CHClCN) ₂ ; C ₂ H ₆ (24.5 l.)	63
C₅H₉N			
<i>n</i> -C ₄ H ₉ CN (1 mole)	<i>n</i> -C ₄ H ₉ MgBr (1 mole)	(<i>n</i> -C ₄ H ₉) ₃ COH (38 g.); (<i>n</i> -C ₄ H ₉) ₂ CO (27 g.); gas (2.5 l.); black residue	64
<i>n</i> -C ₄ H ₉ CN (0.25 mole)	C ₆ H ₅ MgBr (160 g. C ₆ H ₅ Br)	<i>n</i> -C ₄ H ₉ COC ₆ H ₅ (32 g., 79%)	9
<i>n</i> -C ₄ H ₉ CN	C ₆ H ₅ MgBr (1.1 equiv.)	<i>n</i> -C ₄ H ₉ COC ₆ H ₅ (83%)	59
<i>n</i> -C ₄ H ₉ CN	C ₆ H ₅ MgBr (3.0 equiv.)	<i>n</i> -C ₄ H ₉ COC ₆ H ₅ (79%)	59
<i>i</i> -C ₄ H ₉ CN	<i>n</i> -C ₃ H ₇ MgX	<i>i</i> -C ₄ H ₉ CO- <i>n</i> -C ₃ H ₇	45
<i>i</i> -C ₄ H ₉ CN (20 g.)	ω -Camphenyl-MgBr (50 g. C ₁₀ H ₁₅ Br)	ω -Isovalerylcamphene	12
<i>t</i> -C ₄ H ₉ CN	C ₆ H ₅ MgBr (1.5 equiv.) (+ HCl)	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)C=NH·HCl; <i>t</i> -C ₄ H ₉ COC ₆ H ₅ (totaling the equiv. of 72% ketone)	65, 66

* From 8 g. of 1-bromo-2-(4-methyl-3-cyclohexen-1-yl)propane.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₉NO			
C ₂ H ₅ OCH(CH ₃)CN (17 g.)	CH ₃ MgI (40 g. CH ₃ I)	C ₂ H ₅ OCH(CH ₃)COCH ₃ (14 g.)	21
C ₂ H ₅ OCH(CH ₃)CN (14 g.)	C ₂ H ₅ MgI (35 g. C ₂ H ₅ I)	C ₂ H ₅ OCH(CH ₃)COC ₂ H ₅ (13 g.)	21
<i>n</i> -C ₃ H ₇ OCH ₂ CN	CH ₃ MgI (1.5 equiv.)	<i>n</i> -C ₃ H ₇ OCH ₂ COCH ₃	21
<i>i</i> -C ₃ H ₇ OCH ₂ CN	H ₂ C=CHCH ₂ MgBr (2 equiv.)	<i>i</i> -C ₃ H ₇ OCH ₂ C(CH ₂ CH=CH ₂) ₂ NH ₂ (66.3%)	22
HO(CH ₃)(C ₂ H ₅)CCN	CH ₃ MgBr	CH ₃ COC ₂ H ₅ ; <i>t</i> -C ₅ H ₁₁ OH (74%); CH ₃ (C ₂ H ₅)C(OH)COCH ₃	69
HO(CH ₃)(C ₂ H ₅)CCN	CH ₃ MgI	CH ₃ (C ₂ H ₅)C(OH)COCH ₃	24
HO(CH ₃)(C ₂ H ₅)CCN	C ₆ H ₅ MgBr	CH ₃ (C ₂ H ₅)(C ₆ H ₅)COH (72%)	69
<i>i</i> -C ₃ H ₇ CH(OH)CN	C ₂ H ₅ MgBr	<i>i</i> -C ₃ H ₇ CH(OH)COC ₂ H ₅	24
<i>i</i> -C ₃ H ₇ CH(OH)CN	<i>i</i> -C ₃ H ₇ MgI	<i>i</i> -C ₃ H ₇ CH(OH)CO- <i>i</i> -C ₃ H ₇	24
HO(CH ₃) ₂ CCH ₂ CN	CH ₃ MgBr	(CH ₃) ₂ C=CHCOCH ₃ + (CH ₃) ₂ C(OH)CH ₂ COCH ₃ (totaling <i>ca.</i> 50%)	57
C₆H₁₀N₂			
(CH ₃) ₂ NCH(CH ₃)CN	CH ₃ MgI (2 equiv.)	(CH ₃) ₂ N- <i>i</i> -C ₃ H ₇ (14%); (CH ₃) ₂ NCH(CH ₃)COCH ₃ (50%)	18
(CH ₃) ₂ NCH(CH ₃)CN	C ₂ H ₅ MgI (2 equiv.)	(CH ₃) ₂ N- <i>s</i> -C ₄ H ₉ (13%); (CH ₃) ₂ NCH(CH ₃)COC ₂ H ₅ (50%)	18
(CH ₃) ₂ NCH(CH ₃)CN	<i>n</i> -C ₃ H ₇ MgBr (2 equiv.)	(CH ₃) ₂ NCH(CH ₃)CO- <i>n</i> -C ₃ H ₇ (67%)	18
(CH ₃) ₂ NCH(CH ₃)CN	C ₆ H ₅ MgBr (2 equiv.)	(CH ₃) ₂ NCH(CH ₃)C ₆ H ₅ (78%)	18
(CH ₃) ₂ NCH(CH ₃)CN	(CH ₂) ₅ CHMgCl (2 equiv.)	(CH ₃) ₂ NCH(CH ₃)COCH(CH ₂) ₅ (64%)	18
(CH ₃) ₂ NCH(CH ₃)CN	C ₆ H ₅ CH ₂ MgCl (2 equiv.)	(CH ₃) ₂ NCH(CH ₃)CH ₂ C ₆ H ₅ (76%)	18
C₆H₄N₂			
Picolinonitrile (40 g.)	C ₂ H ₅ O(CH ₂) ₃ MgBr (64 g. C ₅ H ₁₁ BrO)	1-Pyridyl 3-ethoxypropyl ketone (62%)	43
Nicotinonitrile (0.5 mole)	CH ₃ MgI (2.0 mole)	3-Acetylpyridine (0.13 mole)	235
Nicotinonitrile (46.8 g., 0.45 mole)	<i>n</i> -C ₃ H ₇ MgBr (221 g., 1.80 moles C ₃ H ₇ Br)	3-Butyryl-4- <i>n</i> -propylpyridine (18.6 g., 22%)	235

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₄N₂ (<i>cont.</i>)			
Nicotinonitrile (45 g.)	C ₂ H ₅ O(CH ₂) ₃ MgBr (60 g. C ₅ H ₁₁ BrO)	1-Pyridyl 3-ethoxypropyl ketone (47%)	43
C₆H₅NO₂			
Furfural cyanohydrin	C ₆ H ₅ MgX	Isobenzofuroin	67
C₆H₈N₂			
(—CH ₂ CH ₂ CN) ₂ (0.25 mole)	C ₂ H ₅ MgBr (excess)	1-Imino-2-cyanocyclopentane; C ₂ H ₆ ; (—CH ₂ CH ₂ COC ₂ H ₅) ₂	204
(—CH ₂ CH ₂ CN) ₂	C ₆ H ₅ MgBr	(—CH ₂ CH ₂ COC ₆ H ₅) ₂ (35%)	204
(—CH ₂ CH ₂ CN) ₂	C ₆ H ₅ CH ₂ MgCl	(—CH ₂ CH ₂ COCH ₂ C ₆ H ₅) ₂ (15%)	204
C₆H₁₀NCl			
<i>i</i> -C ₄ H ₉ CHClCN	C ₂ H ₅ MgBr	1,1-Diethyl-2-isobutylethylenimine (main product)	63
C₆H₁₁N			
<i>n</i> -C ₅ H ₁₁ CN	CH ₃ MgI (1.1 equiv.)	<i>n</i> -C ₅ H ₁₁ COCH ₃ (40%); <i>n</i> -C ₅ H ₁₁ (<i>n</i> -C ₅ H ₁₁ CO)CHCN (> 20%)	60
<i>n</i> -C ₅ H ₁₁ CN (0.25 mole)	C ₆ H ₅ MgBr (160 g. C ₆ H ₅ Br)	<i>n</i> -C ₅ H ₁₁ COC ₆ H ₅ (36.5 g., 83%)	9
<i>n</i> -C ₅ H ₁₁ CN	C ₆ H ₅ MgBr (1.1 equiv.)	<i>n</i> -C ₅ H ₁₁ COC ₆ H ₅ (89%)	59,60
<i>n</i> -C ₅ H ₁₁ CN	C ₆ H ₅ MgBr (3.0 equiv.)	<i>n</i> -C ₅ H ₁₁ COC ₆ H ₅ (83%)	59
<i>i</i> -C ₅ H ₁₁ CN (0.25 mole)	C ₆ H ₅ MgBr (160 g. C ₆ H ₅ Br)	<i>i</i> -C ₅ H ₁₁ COC ₆ H ₅ (22 g., 50%)	9,45
<i>i</i> -C ₅ H ₁₁ CN	C ₆ H ₅ CH ₂ MgCl	<i>i</i> -C ₅ H ₁₁ COCH ₂ C ₆ H ₅	45
C₆H₁₁NO			
C ₂ H ₅ O(CH ₂) ₃ CN	C ₂ H ₅ MgBr (2 equiv.)	C ₂ H ₅ O(CH ₂) ₃ COC ₂ H ₅ (5%); gas; residue; [C ₂ H ₅ O(CH ₂) ₃ CN] ₂	68
<i>n</i> -C ₃ H ₇ OCH(CH ₃)CN (10 g.)	CH ₃ MgI (30 g. CH ₃ I)	<i>n</i> -C ₃ H ₇ OCH(CH ₃)COCH ₃ (7 g.)	21

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₁NO (<i>cont.</i>)			
<i>i</i> -C ₄ H ₉ OCH ₂ CN	CH ₃ MgI (1.5 equiv.)	<i>i</i> -C ₄ H ₉ OCH ₂ COCH ₃	21
CH ₃ (<i>n</i> -C ₃ H ₇)C(OH)CN	C ₆ H ₅ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅)COH (64%)	69
C₆H₁₂N₂			
(CH ₃) ₂ N(CH ₃) ₂ CCN	CH ₃ MgBr	[(CH ₃) ₂ N(CH ₃) ₂ C—] ₂	70
(CH ₃) ₂ N(CH ₃) ₂ CCN	C ₂ H ₅ MgBr	(CH ₃) ₂ NC(CH ₃) ₂ C ₂ H ₅ ; [(CH ₃) ₂ N(CH ₃) ₂ C—] ₂	70
(CH ₃) ₂ N(CH ₃) ₂ CCN	<i>n</i> -C ₃ H ₇ MgBr	(CH ₃) ₂ NC(CH ₃) ₂ - <i>n</i> -C ₃ H ₇ (20%); [(CH ₃) ₂ N(CH ₃) ₂ C—] ₂ (very little)	70
C₇H₃NCl₂			
2,4-Cl ₂ C ₆ H ₃ CN (188 g., 1.1 mole)	CH ₃ MgI (3.4 moles)	2,4-Cl ₂ C ₆ H ₃ COCH ₃ (25%)	205
2,5-Cl ₂ C ₆ H ₃ CN	CH ₃ MgI	2,5-Cl ₂ C ₆ H ₃ COCH ₃ (11.7 g., 83.5%)	205
C₇H₄NBr			
2-BrC ₆ H ₄ CN (12 g.)	4-CH ₃ C ₆ H ₄ MgBr (17 g. C ₇ H ₇ Br)	2-BrC ₆ H ₄ C(=NH)C ₆ H ₄ -4-CH ₃ (isolated as ketone; 15 g., 83%)	71
2-BrC ₆ H ₄ CN (12 g.)	4-CH ₃ OC ₆ H ₄ MgBr (19 g. C ₇ H ₇ BrO)	2-BrC ₆ H ₄ COC ₆ H ₄ -4-OCH ₃ (13 g., 69%)	71
4-BrC ₆ H ₄ CN (18.2 g., 0.1 mole)	C ₆ H ₅ CH ₂ CH ₂ MgBr (0.1 mole)	4-BrC ₆ H ₄ COCH ₂ CH ₂ C ₆ H ₅	236
C₇H₄NCl			
2-ClC ₆ H ₄ CN (26 g.)	8-CH ₃ C ₁₀ H ₆ -1-MgBr (66 g. C ₁₁ H ₉ Br)	8-CH ₃ C ₁₀ H ₆ -1-C(=NH·HCl)C ₆ H ₄ -2-Cl (60 g., 63%)	72
C₇H₅N			
C ₆ H ₅ CN	CH ₃ MgBr	C ₆ H ₅ COCH ₃ (80–89%); 2,4,6-triphenyl- pyridine (5%)	73,74

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₅N (cont.)			
C ₆ H ₅ CN (15 g.)	C ₂ H ₅ MgBr (23 g. C ₂ H ₅ Br)	C ₆ H ₅ C(=NH)C ₂ H ₅ (15 g., crude; 10 g., dist'd); higher-boiling material (3 g.)	75
C ₆ H ₅ CN	C ₂ H ₅ MgI	C ₆ H ₅ COC ₂ H ₅ (80%)	45,73,74
C ₆ H ₅ CN	RMgX*	C ₆ H ₅ C(R)=NH·HCl (60-92%)	76
C ₆ H ₅ CN (15 g.)	<i>n</i> -C ₃ H ₇ MgBr (25 g. C ₃ H ₇ Br)	C ₆ H ₅ C(=NH)- <i>n</i> -C ₃ H ₇ (13 g., crude; 9 g., dist'd); higher-boiling material (3 g.)	75
C ₆ H ₅ CN (15 g.)	<i>i</i> -C ₃ H ₇ MgBr (25 g. C ₃ H ₇ Br)	C ₆ H ₅ C(=NH)- <i>i</i> -C ₃ H ₇ (13 g. crude; 5.8 g., dist'd); higher-boiling material (7 g.)	75
C ₆ H ₅ CN (15 g.)	<i>i</i> -C ₄ H ₉ MgBr (29 g. C ₄ H ₉ Br)	C ₆ H ₅ C(=NH)- <i>i</i> -C ₄ H ₉ (15.4 g., crude; 12 g., dist'd); higher-boiling material (2 g.)	75
C ₆ H ₅ CN (6 g.)	<i>t</i> -C ₄ H ₉ MgCl (12 g. C ₄ H ₉ Cl)	C ₆ H ₅ CO- <i>t</i> -C ₄ H ₉ (7-8 g.)	206,207
C ₆ H ₅ CN (15 g.)	C ₆ H ₅ MgBr (32 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ C=NH (21 g.)	75,76,8
C ₆ H ₅ CN (15 g.)	(CH ₂) ₅ CHMgCl (25 g. C ₆ H ₁₁ Cl)	C ₆ H ₅ C(=NH)CH(CH ₂) ₅ (10.2 g., crude; 3 g., dist'd); C ₆ H ₅ COCH(CH ₂) ₅ (1.167 g.)	75
C ₆ H ₅ CN (12 g.)	C ₆ H ₅ CH ₂ MgCl (28 g. C ₇ H ₇ Cl)	C ₆ H ₅ C(=NH)CH ₂ C ₆ H ₅ (15 g., crude); C ₆ H ₅ COCH ₂ C ₆ H ₅ (1.23 g.)	75,73,74,77
C ₆ H ₅ CN	2-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ COC ₆ H ₄ -2-CH ₃	81
C ₆ H ₅ CN	(C ₂ H ₅) ₂ N(CH ₂) ₃ Cl + Mg	C ₆ H ₅ CO(CH ₂) ₃ N(C ₂ H ₅) ₂	208
C ₆ H ₅ CN (0.05 mole)	C ₆ H ₅ C≡CMgBr (0.072 mole)	2,4,6-Triphenyl-2,5-endo-(2'-phenyl-ethylene)-2,3,4,5-tetrahydropyrimidine (0.23 mole, 40%)	216
C ₆ H ₅ CN (15 g.)	1-C ₁₀ H ₇ MgBr (42 g. C ₁₀ H ₇ Br)	C ₆ H ₅ C(=NH)-1-C ₁₀ H ₇ (21 g.)	75
C ₆ H ₅ CN (20.6 g.)	1-C ₁₀ H ₇ MgBr (49.6 g. C ₁₀ H ₇ Br)	C ₆ H ₅ CO-1-C ₁₀ H ₇	239
C ₆ H ₅ CN (20 g.)	5,6,7,8-Tetrahydronaphthyl-1-MgI (39 g. C ₁₀ H ₁₁ I)	1-Benzoyl-5,6,7,8-tetrahydronaphthalene (7.7 g., 22%)	209
C ₆ H ₅ CN (1.2 equiv.)	ω -Camphenyl-MgBr	ω -Benzoylcamphene	12
C ₆ H ₅ CN (26 ml.)	6-CH ₃ OC ₁₀ H ₆ -2-MgBr (47.4 g. C ₁₁ H ₉ BrO)	C ₆ H ₅ CO-2-C ₁₀ H ₆ -6-OCH ₃ (45%)	175,176

* R = C₂H₅; *n*-C₃H₇; *i*-C₄H₉; C₆H₅; (CH₂)₅CH; 2-CH₃C₆H₄; 4-CH₃C₆H₄; 1-C₁₀H₇.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₅N (<i>cont.</i>)			
C ₆ H ₅ CN	6-C ₂ H ₅ OC ₁₀ H ₆ -2-MgBr	C ₆ H ₅ CO-2-C ₁₀ H ₆ -6-OC ₂ H ₅ (30%)	175
C ₆ H ₅ CN (0.03 mole)	<i>n</i> -C ₁₂ H ₂₅ MgBr (0.025 mole)	C ₆ H ₅ CO- <i>n</i> -C ₁₂ H ₂₅ (>57%)	78
C ₆ H ₅ CN (1.25 g.)	9-Anthryl-MgBr (2.57 g. C ₁₄ H ₉ Br)	α -9-Anthryl- α -phenylmethyleneimine (2.45 g., 87%)	167
C ₆ H ₅ CN (3.2 g.)	9-Phenanthryl-MgBr	9-Benzoylphenanthrene (4.6 g., 65%)	79
C ₆ H ₅ CN	C ₆ H ₅ (2-CH ₃ C ₆ H ₄)CHMgCl	"A complex hydrocarbon" only	80
C ₆ H ₅ CN	2,5-Diphenyl-3-furyl-MgBr	2,5-Diphenyl-3-benzoylfuran ("very poor yield")	233
C₇H₆N₂			
C ₆ H ₅ NHCN (5 g.)	C ₆ H ₅ MgBr (13 g. C ₆ H ₅ Br)	C ₆ H ₅ NHC(=NH)C ₆ H ₅ (1 g., crude)	82
C ₆ H ₅ NHCN (5 g.)	1-C ₁₀ H ₇ MgBr	C ₆ H ₅ NHC(=NH)-1-C ₁₀ H ₇ (trace)	82
C₇H₈NCl			
1-Chloro-2-cyanocyclohexene	CH ₃ MgI	1-Chloro-2-acetylcyclohexene	211
1-Chloro-6-cyanocyclohexene	CH ₃ MgI	Violent reaction; nitrile recovered	13
C₇H₉N			
1-Cyanocyclohexene (20.0 g.)	C ₂ H ₅ MgBr (30.0 g. C ₂ H ₅ Br)	Ethyl 1-cyclohexenyl ketone (2.5 g., crude)	168
1-Cyanocyclohexene	C ₂ H ₅ MgI	Ethyl 1-cyclohexenyl ketone	13
1-Cyanocyclohexene (20 g.)	C ₆ H ₅ CH ₂ MgCl (30 g. C ₇ H ₇ Cl)	Benzyl 1-cyclohexenyl ketone (6-7 g., crude)	168
3-Cyanocyclohexene	C ₂ H ₅ MgI	No ketonic product	13
C₇H₁₂N₂			
CH ₃ CH=CHCH[N(CH ₃) ₂]CN	C ₆ H ₅ MgBr	CH ₃ CH=CHCH[N(CH ₃) ₂]C ₆ H ₅	83
(CH ₂) ₅ NCH ₂ CN	CH ₃ MgI (2 equiv.)	(CH ₂) ₅ NC ₂ H ₅ (50%)	18

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₃NO			
<i>i</i> -C ₅ H ₁₁ OCH ₂ CN	CH ₃ MgI (1.5 equiv.)	<i>i</i> -C ₅ H ₁₁ OCH ₂ COCH ₃	21
C₇H₁₃NO₂			
C ₂ H ₅ OCH ₂ CH(OC ₂ H ₅)CN (23.3 g.)	<i>n</i> -C ₃ H ₇ MgBr (22 ml. C ₃ H ₇ Br)	C ₂ H ₅ OCH ₂ CH(OC ₂ H ₅)C(=NH)- <i>n</i> -C ₃ H ₇ (yielding 6.4 g., 21% ketone)	201
C₇H₁₄N₂			
(CH ₃) ₂ N(<i>n</i> -C ₃ H ₇)CHCN	CH ₃ MgI (2 equiv.)	(CH ₃) ₂ N(<i>n</i> -C ₃ H ₇)CHCOCH ₃ (53%)	18
(CH ₃) ₂ N(CH ₃)(C ₂ H ₅)CCN	C ₂ H ₅ MgX	(CH ₃) ₂ NC(C ₂ H ₅) ₂ CH ₃ ; [(CH ₃) ₂ N(CH ₃)(C ₂ H ₅)C—] ₂ (?)	83
(CH ₃) ₂ N(CH ₃)(C ₂ H ₅)CCN	C ₆ H ₅ MgBr	(CH ₃) ₂ NC(CH ₃)(C ₂ H ₅)C ₆ H ₅	83
(CH ₃) ₂ N(CH ₃)(C ₂ H ₅)CCN	C ₆ H ₅ CH ₂ MgBr	(CH ₃) ₂ NC(CH ₃)(C ₂ H ₅)CH ₂ C ₆ H ₅	83
C₈H₄N₂			
C ₆ H ₄ -1,2-(CN) ₂ (15 g.)	C ₆ H ₅ MgBr (46 g. C ₆ H ₅ Br)	3-Phenylpseudoisoindolone anil	84
C ₆ H ₄ -1,2-(CN) ₂ (10 g.)	C ₆ H ₅ CH ₂ MgCl (2.5 equiv.)	1,1-Dibenzyl-3-aminopseudoisoindole (acid hydr., 1 g.; NH ₄ Cl hydr., 6.5 g.)	85
C₆H₅NO			
C ₆ H ₅ COCN	C ₂ H ₅ MgBr	C ₆ H ₅ COC(=NH·HCN)C ₂ H ₅ ; C ₆ H ₅ (C ₂ H ₅) ₂ COH	86
C ₆ H ₅ COCN	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ COH	86
C ₆ H ₅ COCN	C ₆ H ₅ MgBr (1 equiv.)	(C ₆ H ₅) ₂ CO; C ₆ H ₅ COOH; (C ₆ H ₅) ₃ CCN (all yields poor)	87
C ₆ H ₅ COCN (32.5 g.)	C ₆ H ₅ MgBr (78.0 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ COH; (C ₆ H ₅) ₃ CH	87
C ₆ H ₅ COCN	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ (C ₆ H ₅ CH ₂) ₂ COH	86

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₅NO₂			
2,3-CH ₂ O ₂ C ₆ H ₃ CN (8.5 g.)	C ₂ H ₅ MgBr	2,3-CH ₂ O ₂ C ₆ H ₃ COC ₂ H ₅ (1.4 g.); 2,3-CH ₂ O ₂ C ₆ H ₃ C(=NH)C ₂ H ₅ (8.1 g.)	212
3,4-CH ₂ O ₂ C ₆ H ₃ CN (9.85 g.)	C ₂ H ₅ MgBr	Recovered nitrile (2.3 g.); 3,4-CH ₂ O ₂ C ₆ H ₃ C(=NH)C ₂ H ₅ (9.4 g.)	212
C₈H₆NCl			
C ₆ H ₅ CHClCN (15 g.)	C ₆ H ₅ MgBr (48 g. C ₆ H ₅ Br)	C ₆ H ₅ CH ₂ COC ₆ H ₅ (2 g.); C ₆ H ₅ CH ₂ (C ₆ H ₅)C=NH · HCl	88
C₈H₆NCIO			
4-ClC ₆ H ₄ CH(OH)CN	C ₆ H ₅ CH ₂ MgCl	4-ClC ₆ H ₄ CH(OH)COCH ₂ C ₆ H ₅	89
C₈H₇N			
C ₆ H ₅ CH ₂ CN (1 mole)	CH ₃ MgBr (1 mole)	CH ₄ (20 l.); recovered nitrile; C ₆ H ₅ CH ₂ COCH ₃ ; C ₆ H ₅ CH ₂ CONH ₂ ; C ₆ H ₅ CH ₂ C(=NH)CH(C ₆ H ₅)CN (50%); (C ₆ H ₅ CH ₂ CN) ₃ * (10%)	90
C ₆ H ₅ CH ₂ CN	CH ₃ MgI (1.1 equiv.)	C ₆ H ₅ CH ₂ COCH ₃ (8%); C ₆ H ₅ (C ₆ H ₅ CH ₂ CO)CHCN (71%)	60
C ₆ H ₅ CH ₂ CN	C ₂ H ₅ MgBr (1.1 equiv.)	Recovered nitrile (10%); C ₆ H ₅ (C ₆ H ₅ CH ₂ CO)CHCN (51%); cond'n prod. (36%)	60
C ₆ H ₅ CH ₂ CN	<i>i</i> -C ₃ H ₇ MgBr (1.1 equiv.)	Recovered nitrile (9%); C ₆ H ₅ (C ₆ H ₅ CH ₂ CO)CHCN (64%); cond'n prod. (ca. 15%)	60

* Rondou (90) attributes to this trimer the constitution 2,4-diamino-3,5-diphenyl-6-benzylpyridine.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₇N (<i>cont.</i>)			
C ₆ H ₅ CH ₂ CN	<i>n</i> -C ₄ H ₉ MgBr (1.1 equiv.)	Recovered nitrile (24%); C ₆ H ₅ (C ₆ H ₅ CH ₂ CO)CHCN (23%); cond'n prod. (46%)	60
C ₆ H ₅ CH ₂ CN	<i>t</i> -C ₄ H ₉ MgCl (1.1 equiv.)	C ₆ H ₅ (C ₆ H ₅ CH ₂ CO)CHCN (80%)	60
C ₆ H ₅ CH ₂ CN	<i>n</i> -C ₅ H ₁₁ MgBr (1.1 equiv.)	C ₆ H ₅ (C ₆ H ₅ CH ₂ CO)CHCN (51%); cond'n prod. (31%)	60
C ₆ H ₅ CH ₂ CN	C ₆ H ₅ MgBr (1.1 equiv.)	C ₆ H ₅ CH ₂ COC ₆ H ₅ ; (C ₆ H ₅ —) ₂	4
C ₆ H ₅ CH ₂ CN	C ₆ H ₅ MgBr (1 equiv.)	Recovered nitrile (1-2%); C ₆ H ₅ CH ₂ COC ₆ H ₅ (10%); C ₆ H ₅ CH ₂ C(=NH)CH(C ₆ H ₅)CN (30%); (C ₆ H ₅ CH ₂ CN) ₃ * (35%); (C ₆ H ₅ —) ₂ ; C ₆ H ₆ , C ₆ H ₅ Br, C ₆ H ₆ OH	8
C ₆ H ₅ CH ₂ CN	C ₆ H ₅ MgBr (1.1 equiv.)	C ₆ H ₅ CH ₂ COC ₆ H ₅ (33%); C ₆ H ₅ (C ₆ H ₅ CH ₂ CO)CHCN (15%); cond'n prod. (36%)	60
C ₆ H ₅ CH ₂ CN	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (1.1 equiv.)	C ₆ H ₅ (C ₆ H ₅ CH ₂ CO)CHCN (45%); cond'n prod. (43%)	60
2-CH ₃ C ₆ H ₄ CN	CH ₃ MgBr (3 equiv.)	2-CH ₃ C ₆ H ₄ C(=NH)CH ₃ (35%); 2-CH ₃ C ₆ H ₄ COCH ₃ (20%)	91
2-CH ₃ C ₆ H ₄ CN	CH ₃ MgI	2-CH ₃ C ₆ H ₄ COCH ₃ (66%)	238
2-CH ₃ C ₆ H ₄ CN	CH ₃ MgX	2-CH ₃ C ₆ H ₄ COCH ₃ ("excellent yield")	198
2-CH ₃ C ₆ H ₄ CN	C ₂ H ₅ MgX	2-CH ₃ C ₆ H ₄ COC ₂ H ₅ ("excellent yield")	198,217
2-CH ₃ C ₆ H ₄ CN	C ₂ H ₅ MgBr (3 equiv.)	2-CH ₃ C ₆ H ₄ C(=NH)C ₂ H ₅ (19%); 2-CH ₃ C ₆ H ₄ COC ₂ H ₅ (9%)	91
2-CH ₃ C ₆ H ₄ CN	C ₂ H ₅ MgBr (3 equiv.) (+ HCl)	2-CH ₃ C ₆ H ₄ C(=NH·HCl)C ₂ H ₅ (94%)	91
2-CH ₃ C ₆ H ₄ CN	C ₂ H ₅ MgI	2-CH ₃ C ₆ H ₄ COC ₂ H ₅ (17%)	45
2-CH ₃ C ₆ H ₄ CN (17.5 g.)	C ₆ H ₅ MgBr (32 g. C ₆ H ₅ Br)	2-CH ₃ C ₆ H ₄ C(=NH)C ₆ H ₅ (11 g.)	75

* Described as identical with the trimer of Rondou (90).

TABLE X-I (Continued)

Cyano Comp'd	RMgX	Product(s)	Ref.
C₈H₇N (<i>cont.</i>)			
2-CH ₃ C ₆ H ₄ CN	C ₆ H ₅ MgBr (+ HCl)	2-CH ₃ C ₆ H ₄ C(=NH · HCl)C ₆ H ₅ (85%)	91
2-CH ₃ C ₆ H ₄ CN	C ₆ H ₅ CH ₂ MgCl	2-CH ₃ C ₆ H ₄ COCH ₂ C ₆ H ₅ (20%)	45
2-CH ₃ C ₆ H ₄ CN	C ₆ H ₅ CH ₂ MgCl (+ HCl)	2-CH ₃ C ₆ H ₄ C(=NH · HCl)CH ₂ C ₆ H ₅ (87%)	91
2-CH ₃ C ₆ H ₄ CN (23.4 g.)	1-C ₁₀ H ₇ MgBr (50 g. C ₁₀ H ₇ Br)	2-CH ₃ C ₆ H ₄ C(=NH · HCl)-1-C ₁₀ H ₇ (yielding 37.8 g., 76% ketone)	213
2-CH ₃ C ₆ H ₄ CN (3.2 g.)	9-Phenanthryl-MgBr	9- <i>o</i> -Toluyphenanthrene (5.2 g., 70%)	79
3-CH ₃ C ₆ H ₄ CN	CH ₃ MgI	3-CH ₃ C ₆ H ₄ COCH ₃ (87%)	238
3-CH ₃ C ₆ H ₄ CN	CH ₃ MgX	3-CH ₃ C ₆ H ₄ COCH ₃ ("excellent yield")	198
3-CH ₃ C ₆ H ₄ CN	C ₂ H ₅ MgBr	3-CH ₃ C ₆ H ₄ COC ₂ H ₅ (76.6%)	214
3-CH ₃ C ₆ H ₄ CN	C ₂ H ₅ MgX	3-CH ₃ C ₆ H ₄ COC ₂ H ₅ ("excellent yield")	198, 217
3-CH ₃ C ₆ H ₄ CN	C ₆ H ₅ MgBr	3-CH ₃ C ₆ H ₄ COC ₆ H ₅	81
3-CH ₃ C ₆ H ₄ CN	2-CH ₃ C ₆ H ₄ MgBr	3-CH ₃ C ₆ H ₄ COC ₆ H ₄ -2-CH ₃	81
4-CH ₃ C ₆ H ₄ CN (17 g.)	C ₂ H ₅ MgBr (23 g. C ₂ H ₅ Br)	4-CH ₃ C ₆ H ₄ C(=NH)C ₂ H ₅ (10 g., crude; 5 g., dist'd); higher-boiling material (5 g.)	75
4-CH ₃ C ₆ H ₄ CN (350 g.)	C ₂ H ₅ MgX (168 g. Mg)	4-CH ₃ C ₆ H ₄ COC ₂ H ₅	217
4-CH ₃ C ₆ H ₄ CN	C ₂ H ₅ MgI	4-CH ₃ C ₆ H ₄ COC ₂ H ₅ (46%)	45
4-CH ₃ C ₆ H ₄ CN	<i>n</i> -C ₃ H ₇ MgX	4-CH ₃ C ₆ H ₄ CO- <i>n</i> -C ₃ H ₇	45
4-CH ₃ C ₆ H ₄ CN	<i>n</i> -C ₄ H ₉ MgX	4-CH ₃ C ₆ H ₄ CO- <i>n</i> -C ₄ H ₉	45
4-CH ₃ C ₆ H ₄ CN (17.5 g.)	C ₆ H ₅ MgBr (32 g. C ₆ H ₅ Br)	4-CH ₃ C ₆ H ₄ C(=NH)C ₆ H ₅ (13 g.)	75
4-CH ₃ C ₆ H ₄ CN* (6.5 g.)	C ₆ H ₅ CH ₂ MgCl (18 g. C ₇ H ₇ Cl)	4-CH ₃ C ₆ H ₄ COCH ₂ C ₆ H ₅	92
4-CH ₃ C ₆ H ₄ CN [†] (6.5 g.)	C ₆ H ₅ CH ₂ MgCl (14 g. C ₇ H ₇ Cl)	4-CH ₃ C ₆ H ₄ COCH(C ₆ H ₅)CH ₂ C ₆ H ₅	92
C₈H₇NO			
2-CH ₃ OC ₆ H ₄ CN (16.6 g.)	C ₂ H ₅ MgBr	2-CH ₃ OC ₆ H ₄ C(=NH)C ₂ H ₅ (13 g.)	212
3-CH ₃ OC ₆ H ₄ CN (13.3 g.)	C ₆ H ₅ MgBr (19 g. C ₆ H ₅ Br)	3-CH ₃ OC ₆ H ₄ COC ₆ H ₅ (17.1 g., 77%)	93, 94

* Gradual addition of Et₂O-nitrile solution to Grignard solution; four hours reflux; two hours at room temperature.

[†] Addition xylene-nitrile solution to Grignard solution; six to seven hours reflux.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₇NO (<i>cont.</i>)			
3-CH ₃ OC ₆ H ₄ CN (20 g.)	3-CH ₃ C ₆ H ₄ MgBr (31 g. C ₇ H ₇ Br)	3-CH ₃ OC ₆ H ₄ COC ₆ H ₄ -3-CH ₃ (22 g., 65%)	93
4-CH ₃ OC ₆ H ₄ CN (0.03 mole)	C ₆ H ₅ MgBr (0.025 mole)	4-CH ₃ OC ₆ H ₄ COC ₆ H ₅ ("probably > 90%")	95
4-CH ₃ OC ₆ H ₄ CN (26 g.)	3-CH ₃ C ₆ H ₄ MgBr (41 g. C ₇ H ₇ Br)	4-CH ₃ OC ₆ H ₄ COC ₆ H ₄ -3-CH ₃ (34.9 g., 79%)	93
C ₆ H ₅ CH(OH)CN (66.5 g.)	CH ₃ MgI (213 g. CH ₃ I)	C ₆ H ₅ CH(OH)COCH ₃	97
C ₆ H ₅ CH(OH)CN	C ₆ H ₅ MgX	C ₆ H ₅ CH(OH)COC ₆ H ₅	67
(+)-C ₆ H ₅ CH(OH)CN (7.5 g.)	C ₆ H ₅ MgBr (23 g. C ₆ H ₅ Br)	(-)-C ₆ H ₅ CH(OH)COC ₆ H ₅ (6.18 g.)	96
C₈H₇NO₂			
4-HOC ₆ H ₄ CH(OH)CN	C ₆ H ₅ MgX	4-HOC ₆ H ₄ CH(OH)COC ₆ H ₅	67
C₈H₇NO₂S			
C ₆ H ₅ SO ₂ CH ₂ CN	CH ₃ MgI	"Negative result"	4
C ₆ H ₅ SO ₂ CH ₂ CN	C ₆ H ₅ MgBr	"Negative result"	4
C₈H₆N₂			
C ₆ H ₅ NHCH ₂ CN	CH ₃ MgI (2 equiv.)	C ₆ H ₅ NHC ₂ H ₅	98
C₈H₁₄N₂			
(CH ₂) ₅ NCH(CH ₃)CN	CH ₃ MgI (1 equiv.) + C ₆ H ₅ MgBr (1 equiv.)	(CH ₂) ₅ NCH(CH ₃)C ₆ H ₅	18
(CH ₂) ₅ NCH(CH ₃)CN	CH ₃ MgI (1 equiv.) + C ₆ H ₅ CH ₂ MgCl (1 equiv.)	(CH ₂) ₅ NCH(CH ₃)CH ₂ C ₆ H ₅	18
C₈H₁₂N			
Active 1-Cyano-5-methyl- cyclohexene	CH ₃ MgX	1-Acetyl-5-methylcyclohexene	2
Active 1-Cyano-5-methyl- cyclohexene	C ₂ H ₅ MgX	1-Propionyl-5-methylcyclohexene	2

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₂N (<i>cont.</i>)			
Active 1-Cyano-5-methyl-cyclohexene	<i>i</i> -C ₃ H ₇ MgX	1-Isobutyryl-5-methylcyclohexene	2
C₈H₁₅NO			
H ₅ C ₂ O ₂ CC(C ₂ H ₅) ₂ CN	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CO; (C ₂ H ₅) ₂ CHCOC(C ₂ H ₅) ₂ CO ₂ C ₂ H ₅	99
(<i>n</i> -C ₃ H ₇) ₂ C(OH)CN	C ₆ H ₅ MgBr	(<i>n</i> -C ₃ H ₇) ₂ CO; C ₆ H ₅ (<i>n</i> -C ₃ H ₇) ₂ COH (65%)	69
(<i>n</i> -C ₃ H ₇) ₂ C(OH)CN	C ₆ H ₅ CH ₂ MgCl	(<i>n</i> -C ₃ H ₇) ₂ CO; C ₆ H ₅ CH ₂ (<i>n</i> -C ₃ H ₇) ₂ COH (75%)	69
C₈H₁₇N₃			
(CH ₃) ₂ NCH ₂ CH ₂ CH[N(CH ₃) ₂]CN	C ₆ H ₅ MgBr	(CH ₃) ₂ NCH ₂ CH ₂ CH[N(CH ₃) ₂]C ₆ H ₅	83
C₉H₅N			
C ₆ H ₅ C≡CCN (0.022 mole)	C ₆ H ₅ MgBr (0.039 mole)	2,3,5-Triphenylpyrimidine (0.0013 mole, 6%)	216
C₉H₆NBr			
<i>trans</i> -2-BrCH=CHC ₆ H ₄ CN (4.5 g.)	CH ₃ MgI (6.2 g. CH ₃ I)	1-Methylisoquinoline (0.4 g., 13%)	215
<i>trans</i> -2-BrCH=CHC ₆ H ₄ CN (5.0 g.)	C ₆ H ₅ MgBr (7.6 g. C ₆ H ₅ Br)	1-Phenylisoquinoline (0.79 g., 15.5%)	215
<i>trans</i> -2-BrCH=CHC ₆ H ₄ CN (5.0 g.)	C ₆ H ₅ CH ₂ MgBr (8.2 g. C ₇ H ₇ Br)	1-Benzylisoquinoline (0.2 g., 4%)	215
C₉H₆N₂			
C ₆ H ₅ CH(CN) ₂ (4 g.)	C ₆ H ₅ MgBr (3.3 g. Mg)	Recovered nitrile (3.9 g.)	17
C ₆ H ₅ CH(CN) ₂ (4 g.)	C ₆ H ₅ MgBr (3.3 g. Mg)	C ₆ H ₅ CH[C(=NH)C ₆ H ₅] ₂ (4.1 g.); tar (small am't)	17

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₇N			
C ₆ H ₅ CH=CHCN	CH ₃ MgI	C ₆ H ₅ CH=CHCOCH ₃ (<60%)	100
C ₆ H ₅ CH=CHCN	C ₆ H ₅ MgBr	C ₆ H ₅ CH=CHCOC ₆ H ₅ (68%)*	100
C ₆ H ₅ CH=CHCN	C ₆ H ₅ MgBr	2,4,6-Triphenyl-2,5-endo-(2'-phenyl-ethylene)-2,3,4,5-tetrahydropyrimidine (ca. 40%)†	216
C₉H₇NO			
C ₆ H ₅ COCH ₂ CN	CH ₃ MgBr (3 equiv.)	C ₆ H ₅ COCH ₂ C(=NH)CH ₃ (52%); tar	102
C ₆ H ₅ COCH ₂ CN	C ₂ H ₅ MgBr	C ₆ H ₅ COCH ₂ COC ₂ H ₅	103
C ₆ H ₅ COCH ₂ CN	C ₂ H ₅ MgBr	Dimer (12%); C ₆ H ₅ COCH ₂ C(=NH)C ₂ H ₅ (25%)	102
C ₆ H ₅ COCH ₂ CN	H ₂ C=CHCH ₂ MgBr (1.0-2.5 equiv.)	1.0 equiv., Recovered nitrile (40%); viscous red oil. 2.5 equiv., viscous red oil	102
C ₆ H ₅ COCH ₂ CN	<i>n</i> -C ₃ H ₇ MgBr (0.5-3.0 equiv.)	0.5 equiv., recovered nitrile (90%); 1.0 equiv., recovered nitrile (83%); 2.0 equiv., recovered nitrile (50%); dimer (10%); 3.0 equiv., dimer (60%); recovered nitrile (20%)	102
C ₆ H ₅ COCH ₂ CN	C ₆ H ₅ MgBr (5 equiv.)	(C ₆ H ₅ CO) ₂ CH ₂	103
C₉H₇NO₂			
2,3-(CH ₂) ₂ O ₂ C ₆ H ₃ CN (8 g.)	C ₂ H ₅ MgBr	2,3-(CH ₂) ₂ O ₂ C ₆ H ₃ COC ₂ H ₅ (5.3 g.); 2,3-(CH ₂) ₂ O ₂ C ₆ H ₃ C(=NH)C ₂ H ₅ (2.9 g.)	212

* Hydrolysis with aqueous sulfuric acid.

† Hydrolysis at ca. 0° with aqueous ammonium chloride.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₈NO₂Br			
2,3-(CH ₃ O) ₂ -4-(or 6-)BrC ₆ H ₂ CN (25 g.)	C ₂ H ₅ MgBr	2,3-(CH ₃ O) ₂ -4-(or 6-)BrC ₆ H ₂ C(=NH)C ₂ H ₅ (7.7 g.); 2-C ₂ H ₅ -3-CH ₃ O-4- (or 6-)BrC ₆ H ₂ CN (9.0 g., 36%)	212
C₉H₉N			
CH ₃ (C ₆ H ₅)CHCN	C ₂ H ₅ MgBr (4 equiv.)	CH ₃ (C ₆ H ₅)CHCOC ₂ H ₅	50
CH ₃ (C ₆ H ₅)CHCN	<i>n</i> -C ₃ H ₇ MgBr (4 equiv.)	CH ₃ (C ₆ H ₅)CHCO- <i>n</i> -C ₃ H ₇	50
CH ₃ (C ₆ H ₅)CHCN	C ₆ H ₅ CH ₂ MgCl (4 equiv.)	CH ₃ (C ₆ H ₅)CHCOCH ₂ C ₆ H ₅	50
2-C ₂ H ₅ C ₆ H ₄ CN	CH ₃ MgI	2-C ₂ H ₅ C ₆ H ₄ COCH ₃ (62%)	217
2-C ₂ H ₅ C ₆ H ₄ CN	CH ₃ MgX	2-C ₂ H ₅ C ₆ H ₄ COCH ₃ ("excellent yield")	198
3-C ₂ H ₅ C ₆ H ₄ CN	CH ₃ MgX	3-C ₂ H ₅ C ₆ H ₄ COCH ₃ ("excellent yield")	198
2,4-(CH ₃) ₂ C ₆ H ₃ CN	CH ₃ MgX	2,4-(CH ₃) ₂ C ₆ H ₃ COCH ₃	217
2,6-(CH ₃) ₂ C ₆ H ₃ CN	CH ₃ MgI	No reaction	217
3,5-(CH ₃) ₂ C ₆ H ₃ CN	CH ₃ MgI	3,5-(CH ₃) ₂ C ₆ H ₃ COCH ₃ (63%)	217
C₉H₉O₂			
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN	CH ₃ MgX	2,3-(CH ₃ O) ₂ C ₆ H ₃ COCH ₃	218
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN (10.2 g.)	CH ₃ MgI (9 g. CH ₃ I)	2,3-(CH ₃ O) ₂ C ₆ H ₃ COCH ₃ (6.5 g.)	219
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN (23.9 g.)	C ₂ H ₅ MgBr (32 g. C ₂ H ₅ Br)	2-C ₂ H ₅ -3-CH ₃ OC ₆ H ₃ CN (14 g., 60%); 2,3-(CH ₃ O) ₂ C ₆ H ₃ COC ₂ H ₅ ; 2-C ₂ H ₅ -3-CH ₃ OC ₆ H ₃ COC ₂ H ₅	166
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN (24 g.)	C ₂ H ₅ MgBr (20 g. C ₂ H ₅ Br)	2-C ₂ H ₅ -3-CH ₃ OC ₆ H ₃ CN (14.4 g., 60%)	212
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN (49 g.)	<i>i</i> -C ₃ H ₇ MgBr (61 g. C ₃ H ₇ Br)	2- <i>i</i> -C ₃ H ₇ -3-CH ₃ OC ₆ H ₃ CN (45 g., 81%)	218,212
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN (49 g.)	<i>n</i> -C ₄ H ₉ MgBr (69 g. C ₄ H ₉ Br)	2- <i>n</i> -C ₄ H ₉ -3-CH ₃ OC ₆ H ₃ CN (42.7 g., 80%)	218

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₉O₂ (cont.)			
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN (49 g.)	<i>i</i> -C ₄ H ₉ MgBr (69 g. C ₄ H ₉ Br)	2- <i>i</i> -C ₄ H ₉ -3-CH ₃ OC ₆ H ₄ CN (25.8 g., 45%)	218
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN (12 g.)	<i>t</i> -C ₄ H ₉ MgCl	Recovered nitrile (7.4 g.); 2,3-(CH ₃ O) ₂ C ₆ H ₃ C(=NH)- <i>t</i> -C ₄ H ₉ (4.3 g.)	212
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN (16.3 g.)	C ₆ H ₅ MgBr (15.7 g. C ₆ H ₅ Br)	2-C ₆ H ₅ -3-CH ₃ OC ₆ H ₃ CN (6.5 g., 31%); 2,3-(CH ₃ O) ₂ C ₆ H ₃ COC ₆ H ₅ ; 2-C ₆ H ₅ -3-CH ₃ OC ₆ H ₃ COC ₆ H ₅	218
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN (16.3 g.)	(CH ₂) ₅ CHMgBr (29.3 g. C ₆ H ₁₁ Br)	2-(CH ₂) ₅ CH-3-CH ₃ OC ₆ H ₃ CN (14.6 g., 68%)	218
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN (49 g.)	<i>n</i> -C ₇ H ₁₅ MgBr (72 g. C ₇ H ₁₅ Br)	2-C ₇ H ₁₅ -3-CH ₃ OC ₆ H ₃ CN (40 g., 62%); 2,3-(CH ₃ O) ₂ C ₆ H ₃ CO- <i>n</i> -C ₇ H ₁₅	218
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN (16.3 g.)	1-C ₁₀ H ₇ MgBr (2.8 g. Mg)	2- α -C ₁₀ H ₇ -3-CH ₃ OC ₆ H ₃ CN (1.7 g., 6.5%); 2-HO-3-CH ₃ OC ₆ H ₃ CO-1-C ₁₀ H ₇ + 2,3-(CH ₃ O) ₂ C ₆ H ₃ CO-1-C ₁₀ H ₇ (totalling <i>ca.</i> 35%); resin	101
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN	2-C ₁₀ H ₇ MgBr	2- β -C ₁₀ H ₇ -3-CH ₃ OC ₆ H ₃ CN (7%); 2,3-(CH ₃ O) ₂ C ₆ H ₃ CO-2-C ₁₀ H ₇ ; (2-C ₁₀ H ₇ -) ₂ ; resin	101
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN	3,4-Dihydro-2-naphthyl-MgBr (42 g. C ₁₀ H ₉ Br)	2- β -C ₁₀ H ₇ -3-CH ₃ OC ₆ H ₃ CN (26.3%); 2,3-(CH ₃ O) ₂ C ₆ H ₃ CO-2-C ₁₀ H ₇ (4.9 g.); 3,3',4,4'-tetrahydro-2,2'-binaphthyl (1.5 g.)	101
2,3-(CH ₃ O) ₂ C ₆ H ₃ CN (30 g.)	C ₁₀ H ₁₁ MgCl*	2-(2-C ₁₀ H ₁₁)-3-CH ₃ OC ₆ H ₃ CN (32 g.)	101
2,5-(CH ₃ O) ₂ C ₆ H ₃ CN (10.5 g.)	C ₂ H ₅ MgBr	2,5-(CH ₃ O) ₂ C ₆ H ₃ C(=NH)C ₂ H ₅ (9.5 g.)	212
2,6-(CH ₃ O) ₂ C ₆ H ₃ CN (12 g.)	C ₂ H ₅ MgBr (16 g. C ₂ H ₅ Br)	2,6-(CH ₃ O) ₂ C ₆ H ₃ C(=NH)C ₂ H ₅ (11 g., crude); recovered nitrile (0.8 g.)	212
2,6-(CH ₃ O) ₂ C ₆ H ₃ CN (16.3 g.)	<i>i</i> -C ₄ H ₉ MgBr (32.5 g. C ₄ H ₉ Br)	2,6-(CH ₃ O) ₂ C ₆ H ₃ CO- <i>i</i> -C ₄ H ₉	105

* From 8 g. of Mg and 35 g. of 2-chloro-1,2,3,4-tetrahydronaphthalene.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₉O₂ (cont.)			
3,4-(CH ₃ O) ₂ C ₆ H ₃ CN (10 g.)	C ₂ H ₅ MgBr	3,4-(CH ₃ O) ₂ C ₆ H ₃ C(=NH)C ₂ H ₅ (5.2 g.); recovered nitrile (2.7 g.)	212
3,5-(CH ₃ O) ₂ C ₆ H ₃ CN (3.2 g.)	<i>i</i> -C ₄ H ₉ MgBr (13 g. C ₄ H ₉ Br)	3,5-(CH ₃ O) ₂ C ₆ H ₃ CO- <i>i</i> -C ₄ H ₉	106
3-CH ₃ OC ₆ H ₄ OCH ₂ CN (48 g.)	C ₆ H ₅ CH ₂ MgCl (94.5 g. C ₇ H ₇ Cl)	3-CH ₃ OC ₆ H ₄ OCH ₂ COCH ₂ C ₆ H ₅	107
2-CH ₃ OC ₆ H ₄ CH(OH)CN	C ₆ H ₅ MgX	2-CH ₃ OC ₆ H ₄ CH(OH)COC ₆ H ₅	67
2-CH ₃ OC ₆ H ₄ CH(OH)CN	4-CH ₃ OC ₆ H ₄ MgX	2-CH ₃ OC ₆ H ₄ CH(OH)COC ₆ H ₄ -4-OCH ₃	67
4-CH ₃ OC ₆ H ₄ CH(OH)CN	C ₆ H ₅ MgX	4-CH ₃ OC ₆ H ₄ CH(OH)COC ₆ H ₅	67
4-CH ₃ OC ₆ H ₄ CH(OH)CN (33 g.)	(CH ₂) ₄ CHMgBr (64 g. C ₅ H ₉ Br)	4-CH ₃ OC ₆ H ₄ CH(OH)COCH(CH ₂) ₄ (5 g.)	104
4-CH ₃ OC ₆ H ₄ CH(OH)CN (13.6 g.)	(CH ₂) ₅ CHMgBr (35 g. C ₆ H ₁₁ Br)	4-CH ₃ OC ₆ H ₄ CH(OH)COCH(CH ₂) ₅	104
C₉H₁₀N₂			
4-(CH ₃) ₂ NC ₆ H ₄ CN (0.06 mole)	C ₆ H ₅ MgBr (0.05 mole)	4-(CH ₃) ₂ NC ₆ H ₅ COC ₆ H ₅ (> 60%)	95
C₉H₁₄N₂			
(CH ₂) ₅ NCH(CH=CH ₂)CN	C ₆ H ₅ MgBr	(CH ₂) ₅ NCH(CH=CH ₂)C ₆ H ₅	83
C₉H₁₅NO₂			
H ₅ C ₂ O ₂ CC(C ₂ H ₅) ₂ CN	C ₂ H ₅ MgX* (1 equiv.)	HO(C ₂ H ₅) ₂ CC(C ₂ H ₅) ₂ CN	109
H ₅ C ₂ O ₂ CC(C ₂ H ₅) ₂ CN	C ₂ H ₅ MgX* (2 equiv.)	(C ₂ H ₅) ₂ CO; (C ₂ H ₅) ₂ CHCN; (C ₂ H ₅) ₃ COH; (C ₂ H ₅) ₂ CHCO ₂ C ₂ H ₅ ; (C ₂ H ₅) ₂ CHCOC(C ₂ H ₅) ₂ CO ₂ C ₂ H ₅ ; (C ₂ H ₅) ₂ C(OH)C(C ₂ H ₅) ₂ CN	109
H ₅ C ₆ O ₂ CC(C ₂ H ₅) ₂ CN	C ₆ H ₅ MgBr	(C ₂ H ₅) ₂ CHCO ₂ C ₂ H ₅ ; (C ₆ H ₅) ₂ CO; (C ₂ H ₅) ₂ CHCOC(C ₂ H ₅) ₂ CO ₂ C ₂ H ₅	99
C₉H₁₆N₂			
(CH ₂) ₅ NC(CH ₃) ₂ CN	CH ₃ MgX (2 equiv.)	(CH ₂) ₅ NC(CH ₃) ₃	70
(CH ₂) ₅ NC(CH ₃) ₂ CN	C ₂ H ₅ MgX (2 equiv.)	(CH ₂) ₅ NC(CH ₃) ₂ C ₂ H ₅	70

* X = Br, I.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₆N₂ (<i>cont.</i>)			
(CH ₂) ₅ NC(CH ₃) ₂ CN	<i>n</i> -C ₃ H ₇ MgX (2 equiv.)	(CH ₂) ₅ NC(CH ₃) ₂ - <i>n</i> -C ₃ H ₇	70
C₉H₁₇N			
<i>n</i> -C ₈ H ₁₇ CN	<i>n</i> -C ₈ H ₁₇ MgX	(<i>n</i> -C ₈ H ₁₇) ₂ CO (<i>ca.</i> 65%)	20
C₉H₁₇NO			
4-(4-Morpholinyl)butyronitrile	CH ₃ MgX	5-(4-Morpholinyl)-2-pentanone (66%)	160
4-(4-Morpholinyl)butyronitrile	<i>n</i> -C ₃ H ₇ MgX	7-(4-Morpholinyl)-4-heptanone (50%)	160
C₁₀H₆N₂			
2-Cyanoquinoline	CH ₃ MgI (2.25 equiv.)	2-Acetylquinoline (79%)	110
2-Cyanoquinoline (4.3 g.)	CH ₃ MgI (1 equiv.) + C ₆ H ₅ CH ₂ MgCl (4.7 g. C ₇ H ₇ Cl)	2- <i>α</i> -Toluyquinoline (0.4 g.); 2-acetylquinoline (trace)	110
2-Cyanoquinoline (10 g.)	C ₂ H ₅ MgI (2.25 equiv.)	2-Propionylquinoline (8.2 g., 68%)	110
2-Cyanoquinoline	C ₆ H ₅ MgBr	2-Benzoylquinoline	110
4-Cyanoquinoline (30 g.)	CH ₃ MgI (70 g. CH ₃ I)	4-Acetylquinoline (20 g., 60%)	110
4-Cyanoquinoline (0.3 mole)	C ₂ H ₅ MgI (0.6 mole)	3-Amino-3- <i>γ</i> -quinolylpentane; 4-ethylquinoline (10 g.); 4-propionylquinoline (5 g.)	111
4-Cyanoquinoline (10 g.)	C ₆ H ₅ MgBr (23.6 g.)	4-Benzoylquinoline (5.5 g.)	110, 111
4-Cyanoquinoline	C ₆ H ₅ CH ₂ MgCl (2 equiv.)	Recovered nitrile; 4- <i>α</i> -toluyquinoline; 4-benzylquinoline	111
1-Cyanoisoquinoline (2 g.)	CH ₃ MgI (4.1 g.)	1-Acetylisoquinoline (1.4 g.)	112
1-Cyanoisoquinoline	CH ₃ MgI	1-Acetylisoquinoline (50%)	113
1-Cyanoisoquinoline	C ₆ H ₅ MgBr	1-Benzoylisoquinoline	112
C₁₀H₉NO₃			
2-CH ₃ CO ₂ -3-CH ₃ OC ₆ H ₃ CN (19.1 g.)	C ₂ H ₅ MgBr (33 g. C ₂ H ₅ Br)	2-HO-3-CH ₃ OC ₆ H ₃ COC ₂ H ₅ ; CH ₃ (C ₂ H ₅) ₂ COH	166

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₉NO₃ (cont.)			
(α -C ₄ H ₃ O)CH=C(CO ₂ C ₂ H ₅)CN* (40 g.)	<i>n</i> -C ₃ H ₇ MgBr (70 g. C ₃ H ₇ Br)	<i>n</i> -C ₃ H ₇ (α -C ₄ H ₃ O)CHCH(CO ₂ C ₂ H ₅)CN (40 g., 82%)	220
(α -C ₄ H ₃ O)CH=C(CO ₂ C ₂ H ₅)CN* (20 g.)	<i>i</i> -C ₄ H ₉ MgCl (27 g. C ₄ H ₉ Cl)	<i>i</i> -C ₄ H ₉ (α -C ₄ H ₃ O)CHCH(CO ₂ C ₂ H ₅)CN (24 g.)	220
C₁₀H₁₁N			
C ₂ H ₅ (C ₆ H ₅)CHCN	CH ₃ MgI (4 equiv.)	C ₂ H ₅ (C ₆ H ₅)CHCOCH ₃	50
C ₂ H ₅ (C ₆ H ₅)CHCN	<i>n</i> -C ₃ H ₇ MgBr (4 equiv.)	C ₂ H ₅ (C ₆ H ₅)CHCO- <i>n</i> -C ₃ H ₇	50
C ₂ H ₅ (C ₆ H ₅)CHCN	<i>n</i> -C ₄ H ₉ MgBr (4 equiv.)	C ₂ H ₅ (C ₆ H ₅)CHCO- <i>n</i> -C ₄ H ₉	50
C₁₀H₁₁NO			
C ₆ H ₅ CH ₂ CH ₂ OCH ₂ CN	CH ₃ MgI (1.5 equiv.)	C ₆ H ₅ CH ₂ CH ₂ OCH ₂ COCH ₃	114
2-C ₂ H ₅ -3-CH ₃ OC ₆ H ₃ CN	C ₂ H ₅ MgBr	2-C ₂ H ₅ -3-CH ₃ OC ₆ H ₃ COC ₂ H ₅	166
C₁₀H₁₁NO₂			
2,3-(CH ₃ O) ₂ -5-CH ₃ C ₆ H ₂ CN (12 g.)	C ₂ H ₅ MgBr	2-C ₂ H ₅ -3-CH ₃ O-5-CH ₃ C ₆ H ₂ CN (6.3 g., 52%); 2,3-(CH ₃ O) ₂ -5- CH ₃ C ₆ H ₂ C(=NH)C ₂ H ₅ (4.0 g.)	212
C₁₀H₁₁NO₃			
3,4,5-(CH ₃ O) ₃ C ₆ H ₂ CN (19.3 g.)	<i>i</i> -C ₄ H ₉ MgBr (34.2 g. C ₄ H ₉ Br)	3,4,5-(CH ₃ O) ₃ C ₆ H ₂ CO- <i>i</i> -C ₄ H ₉ (6.5 g.); 3,5-(CH ₃ O) ₂ -4-HOC ₆ H ₂ CO- <i>i</i> -C ₄ H ₉ (?); 3,5-(CH ₃ O) ₂ -4- <i>i</i> -C ₄ H ₉ C ₆ H ₂ CO- <i>i</i> -C ₄ H ₉ (?)	106
3,4,5-(CH ₃ O) ₃ C ₆ H ₂ CN (19.3 g.)	<i>i</i> -C ₄ H ₉ MgBr (2.5 equiv.)	3,4,5-(CH ₃ O) ₃ C ₆ H ₂ CO- <i>i</i> -C ₄ H ₉ (3.8 g.); 3,5-(CH ₃ O) ₂ -4-HOC ₆ H ₂ CO- <i>i</i> -C ₄ H ₉ (4.5 g.)	106

* (α -C₄H₃O) = 2-furyl.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₁NO₃ (cont.)			
3,4,5-(CH ₃ O) ₃ C ₆ H ₂ CN (19.3 g.)	<i>i</i> -C ₄ H ₉ MgBr (4 equiv.)	3,4,5-(CH ₃ O) ₃ C ₆ H ₂ CO- <i>i</i> -C ₄ H ₉ (1.5 g.); 3,5-(CH ₃ O) ₂ -4-HOC ₆ H ₂ CO- <i>i</i> -C ₄ H ₉ (10.0 g.); 3,5-(CH ₃ O) ₂ -4- <i>i</i> -C ₄ H ₉ C ₆ H ₂ CO- <i>i</i> -C ₄ H ₉ (7.7 g., crude)	106
C₁₀H₁₁NS			
C ₆ H ₅ S(CH ₂) ₃ CN	C ₆ H ₅ MgBr	C ₆ H ₅ S(CH ₂) ₃ COC ₆ H ₅	116
C₁₀H₁₂N			
4-Methyl-7-cyanoindan (120 g.)	1-C ₁₀ H ₇ MgBr (195 g. C ₁₀ H ₇ Br)	4-Methyl-7- α -naphthoylindan ketimine hydrochloride (yielding 194 g., 89% ketone)	221
C₁₀H₁₂N₂			
C ₂ H ₅ (C ₆ H ₅)NCH ₂ CN	CH ₃ MgI (2 equiv.)	C ₂ H ₅ (C ₆ H ₅)NCH ₂ COCH ₃	98
(CH ₃) ₂ NCH(C ₆ H ₅)CN	CH ₃ MgI (2 equiv.)	(CH ₃) ₂ NCH(C ₆ H ₅)CH ₃	98
(CH ₃) ₂ NCH(C ₆ H ₅)CN	C ₆ H ₅ MgBr (2 equiv.)	(CH ₃) ₂ NCH(C ₆ H ₅) ₂	98
(CH ₃) ₂ NCH(C ₆ H ₅)CN	C ₆ H ₅ CH ₂ MgCl (2 equiv.)	(CH ₃) ₂ NCH(C ₆ H ₅)CH ₂ C ₆ H ₅	98
C₁₀H₁₈N₂			
(CH ₂) ₅ N(CH ₃)(C ₂ H ₅)CCN	C ₂ H ₅ MgX	(CH ₂) ₅ NC(C ₂ H ₅) ₂ CH ₃	83
(CH ₂) ₅ N(CH ₃)(C ₂ H ₅)CCN	C ₆ H ₅ MgX	(CH ₂) ₅ NC(CH ₃)(C ₂ H ₅)C ₆ H ₅	83
(CH ₂) ₅ N(CH ₃)(C ₂ H ₅)CCN	C ₆ H ₅ CH ₂ MgX	(CH ₂) ₅ NC(CH ₃)(C ₂ H ₅)CH ₂ C ₆ H ₅	83
C₁₀H₁₉N			
<i>n</i> -C ₉ H ₁₉ CN	<i>n</i> -C ₇ H ₁₅ MgX	<i>n</i> -C ₉ H ₁₉ CO- <i>n</i> -C ₇ H ₁₅ (ca. 65%)	20
<i>n</i> -C ₉ H ₁₉ CN	<i>n</i> -C ₈ H ₁₇ MgX	<i>n</i> -C ₉ H ₁₉ CO- <i>n</i> -C ₈ H ₁₇ (ca. 65%)	20

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₉NO			
<i>n</i> -C ₈ H ₁₇ OCH ₂ CN	CH ₃ MgI (excess)	<i>n</i> -C ₈ H ₁₇ OCH ₂ COCH ₃	114
C₁₁H₇N			
1-C ₁₀ H ₇ CN (0.20 mole)	RMgBr (0.22 mole RBr)	1-C ₁₀ H ₇ C(=NH)R*	222
1-C ₁₀ H ₇ CN (86.4 g.)	C ₂ H ₅ MgBr (80 g. C ₂ H ₅ Br)	1-C ₁₀ H ₇ C(=NH)C ₂ H ₅ (yielding 90 g., 89% ketone)	223,214
1-C ₁₀ H ₇ CN	4-ClC ₆ H ₄ MgBr	4-ClC ₆ H ₄ (1-C ₁₀ H ₇)C=NH·HCl	117
1-C ₁₀ H ₇ CN	2-CH ₃ OC ₆ H ₄ MgBr	2-CH ₃ OC ₆ H ₄ CO-1-C ₁₀ H ₇ (87%)	118
1-C ₁₀ H ₇ CN (17 g.)	4-(7-Methylindanyl)-MgBr (22 g. C ₁₀ H ₁₁ Br)	4- α -Naphthoyl-7-methylindan ketimine hydrochloride (yielding 14.6 g., 49% ketone)	213
1-C ₁₀ H ₇ CN (15 g.)	1-C ₁₀ H ₇ MgBr (30 g. C ₁₀ H ₇ Br)	(1-C ₁₀ H ₇) ₂ C=NH (20.7 g.)	119
2-C ₁₀ H ₇ CN	C ₂ H ₅ MgBr	2-C ₁₀ H ₇ COC ₂ H ₅ (67%)	214
2-C ₁₀ H ₇ CN	C ₂ H ₅ MgI (1.5 equiv.)	C ₂ H ₅ CO-2-C ₁₀ H ₇ (95%)	120
2-C ₁₀ H ₇ CN	2-ClC ₆ H ₄ MgBr	2-ClC ₆ H ₄ (2-C ₁₀ H ₇)C=NH·HCl	121
2-C ₁₀ H ₇ CN (5 g.)	4-ClC ₆ H ₄ MgBr (7.5 g. C ₆ H ₄ BrCl)	4-ClC ₆ H ₄ (2-C ₁₀ H ₇)C=NH·HCl (yielding 7 g., 81% ketone)	117
2-C ₁₀ H ₇ CN (10 g.)	C ₆ H ₅ MgBr (15 g. C ₆ H ₅ Br)	2-C ₁₀ H ₇ COC ₆ H ₅ (70%)	174,176
2-C ₁₀ H ₇ CN	2-CH ₃ OC ₆ H ₄ MgBr	2-CH ₃ OC ₆ H ₄ CO-2-C ₁₀ H ₇ (74%)	118
2-C ₁₀ H ₇ CN (15 g.)	1-C ₁₀ H ₇ MgBr (30 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ (2-C ₁₀ H ₇)C=NH (21.5 g.)	119
2-C ₁₀ H ₇ CN (15 g.)	2-C ₁₀ H ₇ MgBr (30 g. C ₁₀ H ₇ Br)	(2-C ₁₀ H ₇) ₂ C=NH (22.3 g.)	119
2-C ₁₀ H ₇ CN (33 g.)	2-CH ₃ C ₁₀ H ₆ -1-MgBr (54 g. C ₁₁ H ₉ Br)	2-C ₁₀ H ₇ C(=NH·HCl)-1-C ₁₀ H ₆ -2-CH ₃ (78 g.)	213

* The ketimines were converted to the corresponding ketones in the indicated yields for R =: CH₃, 52%; C₂H₅, 37%; *n*-C₃H₇, 63%; *i*-C₃H₇, 39%; *n*-C₄H₉, 46%; *i*-C₄H₉, 48%; *n*-C₅H₁₁, 44%; *i*-C₅H₁₁, 51%; C₆H₅, 55%; (CH₂)₅CH, 37%; *n*-C₆H₁₃, 35%.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₈N₂O			
4-Cyano-6-methoxyquinoline (10 g.)	CH ₃ MgI (19.3 g. CH ₃ I)	4-Acetyl-6-methoxyquinoline	110
6-Methoxy-8-cyanoquinoline (18 g.)	CH ₃ MgBr (5 g. Mg)	6-Methoxy-8-acetoquinoline (16 g., 79%)	225
6-Methoxy-8-cyanoquinoline	C ₂ H ₅ MgI	6-Methoxy-8-propionylquinoline	122
C₁₁H₉N			
1-Methyl-5-cyanonaphthalene	CH ₃ MgI (2 ml. CH ₃ I)	1-Methyl-5-acetylnaphthalene (2.5 g.)	124
C₁₁H₁₀N₂			
2-Cyano-3,3-dimethyl-3-pseudoindole (10 g.)	CH ₃ MgI (1.6 g. Mg)	2-Acetyl-3,3-dimethyl-3-pseudoindole	125
2-Cyano-3,3-dimethyl-3-pseudoindole (10 g.)	C ₆ H ₅ MgBr (3 g. C ₆ H ₅ Br)	2-Benzimino-3,3-dimethyl-3-pseudoindole	125
C₁₁H₁₁N			
4-Methyl-7-cyanoindan (2.8 g.)	5-BrC ₁₀ H ₆ -2-MgBr (5 g. C ₁₀ H ₆ Br ₂)	4-Methyl-7-(5-bromo-2-naphthoyl)indan (3.2 g., 50%)	226
4-Methyl-7-cyanoindan (2.0 g.)	6-ClC ₁₀ H ₆ -2-MgBr (3 g. C ₁₀ H ₆ BrCl)	4-Methyl-7-(6-chloro-2-naphthoyl)indan (2.5 g., 63%)	226
4-Methyl-7-cyanoindan (8.5 g.)	6-CH ₃ OC ₁₀ H ₆ -1-MgI (15 g. C ₁₀ H ₉ IO)	4-Methyl-7-(6-methoxy-1-naphthoyl)indan (63%)	226
4-Cyano-7-methylindan	1-C ₁₀ H ₇ MgBr	4-(1-Naphthoyl)-7-methylindan (83%)	126
2-Cyano-5,6,7,8-tetrahydronaphthalene	C ₆ H ₅ MgBr	2-Benzoyl-5,6,7,8-tetrahydronaphthalene (76%)	209
C₁₁H₁₁NO₂			
2-H ₂ C=CHCH ₂ O-3-CH ₃ OC ₆ H ₃ CN (38 g.)	C ₂ H ₅ MgBr (22 g. C ₂ H ₅ Br)	2-C ₂ H ₅ -3-CH ₃ OC ₆ H ₃ CN (4.1 g.); recovered nitrile (16.3 g.)	166

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₂NCl			
ClCH ₂ CH ₂ C(CH ₃)(C ₆ H ₅)CN	C ₆ H ₅ MgBr (<i>ca.</i> 3 equiv.)	2,3-Diphenyl-3-methyl-Δ ¹ -pyrroline (78%)	123
C₁₁H₁₃N			
<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CHCN	CH ₃ MgI (4 equiv.)	<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CHCOCH ₃	50
<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CHCN	C ₂ H ₅ MgBr (4 equiv.)	<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CHCOC ₂ H ₅	50
<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CHCN	<i>n</i> -C ₄ H ₉ MgBr (4 equiv.)	<i>n</i> -C ₃ H ₇ (C ₆ H ₅)CHCO- <i>n</i> -C ₄ H ₉	50
CH ₃ (C ₂ H ₅)(C ₆ H ₅)CCN	C ₆ H ₅ MgBr (1.25 equiv.)	CH ₃ (C ₂ H ₅)(C ₆ H ₅)CCOC ₆ H ₅ (55%)	66
CH ₃ (C ₂ H ₅)(C ₆ H ₅)CCN	C ₆ H ₅ MgBr	CH ₃ (C ₂ H ₅)(C ₆ H ₅)CCOC ₆ H ₅ ("excellent yield")	65
C₁₁H₁₃NO			
C ₂ H ₅ (C ₆ H ₅ CH ₂ O)CHCN	C ₂ H ₅ MgBr	C ₆ H ₅ CH ₂ NHC(C ₂ H ₅) ₂ CH(OH)C ₂ H ₅	229
C ₂ H ₅ (C ₆ H ₅ CH ₂ O)CHCN	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ NHC(C ₆ H ₅) ₂ CH(OH)C ₂ H ₅	229
2,4,6-(CH ₃) ₃ C ₆ H ₂ CH(OH)CN (0.1 mole)	C ₆ H ₅ MgBr (0.5 mole C ₆ H ₅ Br)	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH(NH ₂ ·HCl)C ₆ H ₅ (16 g., 55%)	127
C₁₁H₁₃NO₂			
2,6-(C ₂ H ₅ O) ₂ C ₆ H ₃ CN	RMgX*	Unchanged nitrile	92
3,5-(CH ₃ O) ₂ C ₆ H ₃ CH(CH ₃)CN (41.5 g.)	<i>n</i> -C ₃ H ₇ CH(CH ₃)CH ₂ MgBr (98.5 g. C ₆ H ₁₃ Br)	3,5-(CH ₃ O) ₂ C ₆ H ₃ CH(CH ₃)COCH ₂ CH(CH ₃)- <i>n</i> -C ₃ H ₇ (30 g., 52%)	128
C₁₁H₁₄N₂			
(CH ₃) ₂ NCH(CH ₂ C ₆ H ₅)CN	C ₆ H ₅ MgBr (2 equiv.)	(CH ₃) ₂ NCH(C ₆ H ₅)CH ₂ C ₆ H ₅	98
C₁₁H₁₅NO₂			
Ethyl α-cyano-α-cyclohexylidene- acetate (24.0 g.)	CH ₃ MgI (19.5 g. CH ₃ I)	Ethyl α-cyano-α-(1-methylcyclohexyl)ace- tate (45%)	224

* R = CH₃, C₂H₅, C₆H₅, C₆H₅CH₂.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₅NO₂ (<i>cont.</i>)			
Ethyl α -cyano- α -cyclohexylideneacetate (15.0 g.)	<i>n</i> -C ₁₀ H ₂₁ MgBr (25.0 g. C ₁₀ H ₂₁ Br)	Ethyl α -cyano- α -(1- <i>n</i> -decylcyclohexyl)acetate (14%)	224
C₁₁H₂₁N			
<i>n</i> -C ₁₀ H ₂₁ CN	C ₂ H ₅ MgBr	<i>n</i> -C ₁₀ H ₂₁ COC ₂ H ₅ ("poor yield")	230
<i>n</i> -C ₁₀ H ₂₁ CN	<i>n</i> -C ₆ H ₁₃ MgX	<i>n</i> -C ₁₀ H ₂₁ CO- <i>n</i> -C ₆ H ₁₃ (<i>ca.</i> 65%)	20
C₁₂H₉N			
1-C ₁₀ H ₇ CH ₂ CN (30 g., 0.18 mole)	C ₂ H ₅ MgBr (18.5 g., 0.17 mole C ₂ H ₅ Br)	1-C ₁₀ H ₇ CH ₂ COC ₂ H ₅ (5.3 g., 0.027 mole, 16%); polymeric material	234
1-Methyl-7-cyanonaphthalene (3.3 g.)	CH ₃ MgI (4.3 g. CH ₃ I)	1-Methyl-7-acetylnaphthalene	129
C₁₂H₉NO			
2-CH ₃ OC ₁₀ H ₆ -1-CN (11 g.)	C ₂ H ₅ MgBr (14 g. C ₂ H ₅ Br)	2-CH ₃ OC ₁₀ H ₇ (2 g.); 2-HOC ₁₀ H ₇ (1.7 g.); 2-CH ₃ OC ₁₀ H ₆ -1-C(=NH)C ₂ H ₅ (isolated as ketone, 1.7 ml.); recovered nitrile (1.0 g.)	231
2-CH ₃ OC ₁₀ H ₆ -1-CN (11 g.)	C ₆ H ₅ CH ₂ MgCl (16 ml. C ₇ H ₇ Cl)	2-CH ₃ OC ₁₀ H ₆ -1-C(=NH·HCl)CH ₂ C ₆ H ₅ ; recovered nitrile (2.3 g.)	231
C₁₂H₁₀N₂O			
4-Cyano-6-ethoxyquinoline	CH ₃ MgI (2.5 equiv.)	4-Acetyl-6-ethoxyquinoline (80%)	130
4-Cyano-6-ethoxyquinoline	C ₂ H ₅ MgI (2.5 equiv.)	4-Propionyl-6-ethoxyquinoline	130
C₁₂H₁₁NO₂			
C ₆ H ₅ CH=C(CO ₂ C ₂ H ₅)CN	CH ₃ MgI	C ₆ H ₅ CH(CH ₃)CH(CO ₂ C ₂ H ₅)CN	131

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₁₁NO₂ (cont.)			
C ₆ H ₅ CH=C(CO ₂ C ₂ H ₅)CN	<i>i</i> -C ₃ H ₇ MgBr	C ₆ H ₅ CH(<i>i</i> -C ₃ H ₇)CH(CO ₂ C ₂ H ₅)CN	131
C ₆ H ₅ CH=C(CO ₂ C ₂ H ₅)CN (20 g.)	C ₆ H ₅ MgBr (2.75 g. Mg)	(C ₆ H ₅) ₂ CHCH(CO ₂ C ₂ H ₅)CN (25.4 g.)	131
C ₆ H ₅ CH=C(CO ₂ C ₂ H ₅)CN	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ CH(C ₆ H ₅)CH(CO ₂ C ₂ H ₅)CN (isolated, after hydrolysis, as the corresponding malonamic acid)	131
C ₆ H ₅ CH=C(CO ₂ C ₂ H ₅)CN	C ₆ H ₅ C≡CMgBr	C ₆ H ₅ C≡CCH(C ₆ H ₅)CH(CO ₂ C ₂ H ₅)CN ("excellent yield")	131
C ₆ H ₅ CH=C(CO ₂ C ₂ H ₅)CN	1-C ₁₀ H ₇ MgBr	C ₆ H ₅ (1-C ₁₀ H ₇)CHCH(CO ₂ C ₂ H ₅)CN	131
C₁₂H₁₂N₂O₂			
1-Cyanohydrohydrastinine	CH ₃ MgI (2 equiv.)	1-Methylhydrohydrastinine	98
C₁₂H₁₄NCl			
ClCH ₂ CH ₂ C(C ₂ H ₅)(C ₆ H ₅)CN (20.8 g.)	C ₆ H ₅ MgBr (50 g. C ₆ H ₅ Br)	2,3-Diphenyl-3-ethyl-Δ ¹ -pyrroline (70%)	123
C₁₂H₁₅N			
C ₆ H ₅ (C ₂ H ₅) ₂ CCN	C ₆ H ₅ MgBr	C ₆ H ₅ (C ₂ H ₅) ₂ CCOC ₆ H ₅	65
C ₆ H ₅ (C ₂ H ₅) ₂ CCN	C ₆ H ₅ MgBr (1.25 equiv.) (+ HBr)	C ₆ H ₅ (C ₂ H ₅) ₂ CC(=NH·HBr)C ₆ H ₅	66
C₁₂H₂₁N			
H ₂ C=CH(CH ₂) ₉ CN (24.5 g.)	CH ₃ MgI (14 g. Mg)	CH ₃ CO(CH ₂) ₉ CH=CH ₂ (19 g.)	133
C₁₂H₂₃N			
<i>n</i> -C ₁₁ H ₂₃ CN	<i>n</i> -C ₄ H ₉ MgBr (sl. excess)	<i>n</i> -C ₄ H ₉ CO- <i>n</i> -C ₁₁ H ₂₃ (68%)	134
<i>n</i> -C ₁₁ H ₂₃ CN	<i>n</i> -C ₅ H ₁₁ MgX	<i>n</i> -C ₁₁ H ₂₃ CO- <i>n</i> -C ₅ H ₁₁ (ca. 65%)	20
<i>n</i> -C ₁₁ H ₂₃ CN (1.5-2 moles)	C ₆ H ₅ MgBr (sl. excess)	<i>n</i> -C ₁₁ H ₂₃ COC ₆ H ₅ (75-90%)*	163

* Range of yields claimed for series of nitriles treated.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₂₃N (<i>cont.</i>)			
<i>n</i> -C ₁₁ H ₂₃ CN	<i>n</i> -C ₆ H ₁₃ MgX	<i>n</i> -C ₁₁ H ₂₃ CO- <i>n</i> -C ₅ H ₁₁ (<i>ca.</i> 65%)	20
<i>n</i> -C ₁₁ H ₂₃ CN (293 g., 1.61 mole)	9-Phenanthryl-MgBr (508 g., 1.98 mole C ₁₄ H ₉ Br)	Hendecyl 9-phenanthryl ketone (465 g., 80%)	228
C₁₃H₉N			
2-C ₆ H ₅ C ₆ H ₄ CN	C ₆ H ₅ MgBr	C ₆ H ₅ COC ₆ H ₄ -2-C ₆ H ₅ (76%)	135
C₁₃H₉NO			
α -Phenyl- β -(2-furyl)acrylonitrile	CH ₃ MgI	α -Phenyl- β -(2-furyl)butyronitrile (80%)	227
α -Phenyl- β -(2-furyl)acrylonitrile (20 g.)	C ₂ H ₅ MgBr (25 g. C ₂ H ₅ Br)	α -Phenyl- β -(2-furyl)valeronitrile (20 g.)	136
α -Phenyl- β -(2-furyl)acrylonitrile	<i>n</i> -C ₃ H ₇ MgBr	α -Phenyl- β -(2-furyl)capronitrile (80%)	136
α -Phenyl- β -(2-furyl)acrylonitrile (25 g.)	<i>i</i> -C ₄ H ₉ MgCl (27 g. C ₄ H ₉ Cl)	α -Phenyl- β -(2-furyl)- γ -methylcapronitrile (25 g.)	136
α -Phenyl- β -(2-furyl)acrylonitrile	<i>i</i> -C ₅ H ₁₁ MgBr	α -Phenyl- β -(2-furyl)- δ -methylenanthronitrile (33%)	227
α -Phenyl- β -(2-furyl)acrylonitrile	C ₆ H ₅ CH ₂ MgCl	α , γ -Diphenyl- β -(2-furyl)butyronitrile (80%)	227
α -Phenyl- β -(2-furyl)acrylonitrile	4-CH ₃ C ₆ H ₄ MgBr	α -Phenyl- β -(2-furyl)- β -4-tolylpropionitrile (20%)	227
C₁₃H₁₄N₂O			
1-Benzyl-5-methyl-5-cyano-2-pyrrolidone (6 g.)	CH ₃ MgI (9.95 g. CH ₃ I)	1-Benzyl-5-methyl-5-acetyl-2-pyrrolidone	137
1-Benzyl-5-methyl-5-cyano-2-pyrrolidone (6 g.)	C ₂ H ₅ MgI (10.9 g. C ₂ H ₅ I)	1-Benzyl-5-methyl-5-propionyl-2-pyrrolidone (3.4 g.)	137
1-Benzyl-5-methyl-5-cyano-2-pyrrolidone	C ₆ H ₅ MgBr	1-Benzyl-5-methyl-5-benzoyl-2-pyrrolidone	137

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₁₅N			
4-Cyano-7-isopropylindan (13 g.)	1-C ₁₀ H ₇ MgBr (22 g. C ₁₀ H ₇ Br)	4-(7-Isopropyl)hydrindenyl-1-naphthyl ketimine hydrochloride (25 g., 100%)	138
C₁₃H₁₅NO			
2,4,6-(CH ₃) ₃ C ₆ H ₂ (CH ₃ O)C=CHCN	C ₆ H ₅ MgBr (<i>ca.</i> 1 to <i>ca.</i> 4 equiv.)*	2,4,6-(CH ₃) ₃ C ₆ H ₂ (CH ₃ O)C=CHC(=NH·HBr)C ₆ H ₅ ; 2,4,6-(CH ₃) ₃ C ₆ H ₂ (CH ₃ O)C=CHCOC ₆ H ₅ ; 2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂ COC ₆ H ₅ ; 2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂ C(=NH)C ₆ H ₅ ; recovered nitrile	108
C₁₃H₁₆NCl			
ClCH ₂ CH ₂ C(<i>n</i> -C ₃ H ₇)(C ₆ H ₅)CN	C ₆ H ₅ MgBr (<i>ca.</i> 3 equiv.)	2,3-Diphenyl-2- <i>n</i> -propyl-Δ ¹ -pyrroline (58%)	123
C₁₃H₁₆N₂			
(CH ₂) ₅ NCH(C ₆ H ₅)CN (70 g.)	C ₂ H ₅ MgBr (17 g. Mg)	(CH ₂) ₅ NCH(C ₂ H ₅)C ₆ H ₅ (59 g., 80%)	140
(CH ₂) ₅ NCH(C ₆ H ₅)CN (50 g.)	C ₆ H ₅ MgBr (78.5 g. C ₆ H ₅ Br)	(CH ₂) ₅ NCH(C ₆ H ₅) ₂ (52 g., 83%)	140
(CH ₂) ₅ NCH(C ₆ H ₅)CN (40 g.)	C ₆ H ₅ CH ₂ MgCl (50 g. C ₇ H ₇ Cl)	(CH ₂) ₅ NCH(C ₆ H ₅)CH ₂ C ₆ H ₅ (60%)	140
C₁₃H₂₅N			
<i>n</i> -C ₁₂ H ₂₅ CN (430 g.)	<i>n</i> -C ₃ H ₇ MgCl	<i>n</i> -C ₁₂ H ₂₅ CO- <i>n</i> -C ₃ H ₇ (265 g., 50%)	141
<i>n</i> -C ₁₂ H ₂₅ CN	<i>n</i> -C ₄ H ₉ MgX	<i>n</i> -C ₁₂ H ₂₅ CO- <i>n</i> -C ₄ H ₉ (<i>ca.</i> 65%)	20
<i>n</i> -C ₁₂ H ₂₅ CN	<i>n</i> -C ₅ H ₁₁ MgX	<i>n</i> -C ₁₂ H ₂₅ CO- <i>n</i> -C ₅ H ₁₁ (<i>ca.</i> 65%)	20
C₁₄H₈N₂			
9,10-Dicyanoanthracene	CH ₃ MgI	No reaction	142
9,10-Dicyanoanthracene	C ₂ H ₅ MgBr	Reaction with one cyano group	142

* Nine experiments.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₈N₂ (<i>cont.</i>)			
9,10-Dicyanoanthracene	C ₆ H ₅ MgBr	No reaction	142
C₁₄H₉N			
1-Cyanofluorene (13.27 g.)	C ₆ H ₅ MgBr	1-Benzoylfluorene (7.78 g.)	209
4-Cyanofluorene (5 g.)	C ₆ H ₅ MgBr (4.4 ml. C ₆ H ₅ Br)	4-Benzoylfluorene (3.64 g., 56%)	209
C₁₄H₁₁N			
2-C ₆ H ₅ CH ₂ C ₆ H ₄ CN (11.0 g.)	C ₆ H ₅ MgBr (13.4 g. C ₆ H ₅ Br)	2-C ₆ H ₅ CH ₂ C ₆ H ₄ C(=NH)C ₆ H ₅	143
2-C ₆ H ₅ CH ₂ C ₆ H ₄ CN (10.0 g.)	C ₆ H ₅ MgBr (8.5 g. C ₆ H ₅ Br)	2-C ₆ H ₅ CH ₂ C ₆ H ₄ COC ₆ H ₅ (12.5 g.)	162
(C ₆ H ₅) ₂ CHCN (7.5 g.)	C ₆ H ₅ MgBr (15.0 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ CHCOC ₆ H ₅ (2.0 g.); recovered nitrile (1.5 g.); [NC(C ₆ H ₅) ₂ C—] ₂ (very little)	88
(C ₆ H ₅) ₂ CHCN	2-CH ₃ C ₆ H ₄ MgBr	No reaction	80
(C ₆ H ₅) ₂ CHCN (5 g.)	3-CH ₃ C ₆ H ₄ MgBr (13 g. C ₇ H ₇ Br)	(C ₆ H ₅) ₂ CHCOC ₆ H ₄ -3-CH ₃	80
(CH ₂) ₂ C(1-C ₁₀ H ₇)CN (38.6 g.)	C ₆ H ₅ MgBr (90.0 g. C ₆ H ₅ Br)	(CH ₂) ₂ C(1-C ₁₀ H ₇)C=NH	144
C₁₄H₁₃NO₂			
C ₆ H ₅ CH=CHCH=C(CO ₂ C ₂ H ₅)CN (1 mole)	C ₂ H ₅ MgBr (2.5 mole)	C ₆ H ₅ CH=CHCH(C ₂ H ₅)CH(CO ₂ C ₂ H ₅)CN (quant.)	145
C ₆ H ₅ CH=CHCH=C(CO ₂ C ₂ H ₅)CN	C ₆ H ₅ MgBr	C ₆ H ₅ CH=CHCH(C ₆ H ₅)CH(CO ₂ C ₂ H ₅)CN	145
C₁₄H₁₂N₂			
C ₆ H ₅ NH(C ₆ H ₅)CHCN (52 g.)	C ₂ H ₅ MgBr (12 g. Mg)	Gas (8.4 l.); C ₆ H ₅ NH ₂ ; [C ₆ H ₅ NH(C ₆ H ₅)CH—] ₂ (30%)	140
C ₆ H ₅ NH(C ₆ H ₅)CHCN (52 g.)	C ₆ H ₅ MgBr (78.5 g. C ₆ H ₅ Br)	[C ₆ H ₅ NH(C ₆ H ₅)CH—] ₂ (25%); C ₆ H ₅ CH=NC ₆ H ₅ (15 g.); C ₆ H ₅ NH ₂	140

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₇N			
C ₆ H ₅ [(CH ₂) ₅ CH]CHCN	C ₂ H ₅ MgBr (1 equiv.)	C ₆ H ₅ [(CH ₂) ₅ CH]CHCOC ₂ H ₅	146
C ₆ H ₅ [(CH ₂) ₅ CH]CHCN	<i>n</i> -C ₃ H ₇ MgCl (1 equiv.)	C ₆ H ₅ [(CH ₂) ₅ CH]CHCO- <i>n</i> -C ₃ H ₇	146
C ₆ H ₅ [(CH ₂) ₅ CH]CHCN	<i>i</i> -C ₃ H ₇ MgCl (1 equiv.)	C ₆ H ₅ [(CH ₂) ₅ CH]CHCO- <i>i</i> -C ₃ H ₇	146
C ₆ H ₅ [(CH ₂) ₅ CH]CHCN	C ₆ H ₅ CH ₂ MgCl (1 equiv.)	C ₆ H ₅ [(CH ₂) ₅ CH]COCH ₂ C ₆ H ₅	146
C₁₄H₁₇NO			
2,4,6-(CH ₃) ₃ C ₆ H ₂ (CH ₃ O)C=	C ₆ H ₅ MgBr (7.3 g. C ₆ H ₅ Br)	2,4,6-(CH ₃) ₃ C ₆ H ₂ (CH ₃ O)C=	108
C(CH ₃)CN (2.0 g.)		C(CH ₃)C(=NH·HBr)C ₆ H ₅ (1.3 g.); 2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH(CH ₃)COC ₆ H ₅	
C₁₄H₁₈NCl			
ClCH ₂ CH ₂ C(<i>n</i> -C ₄ H ₉)(C ₆ H ₅)CN	C ₆ H ₅ MgBr (<i>ca.</i> 3 equiv.)	2,3-Diphenyl-2- <i>n</i> -butyl-Δ ¹ -pyrroline (35%)	123
C₁₄H₂₇N			
<i>n</i> -C ₁₃ H ₂₇ CN	<i>n</i> -C ₃ H ₇ MgX	<i>n</i> -C ₁₃ H ₂₇ COC ₂ H ₅ (<i>ca.</i> 65%)	20
<i>n</i> -C ₁₃ H ₂₇ CN	<i>n</i> -C ₄ H ₉ MgX	<i>n</i> -C ₁₃ H ₂₇ CO- <i>n</i> -C ₄ H ₉ (<i>ca.</i> 65%)	20, 134
<i>n</i> -C ₁₃ H ₂₇ CN (1.5-2 moles)	C ₆ H ₅ MgBr (sl. excess)	<i>n</i> -C ₁₃ H ₂₇ COC ₆ H ₅ (75-90%)*	163
<i>i</i> -C ₆ H ₁₃ CH(CH ₃)CH(CH ₂ CH ₂ - OC ₂ H ₅)CH	CH ₃ MgI	<i>i</i> -C ₆ H ₁₃ CH(CH ₃)CH(CH ₂ CH ₂ OC ₂ H ₅)COCH ₃	164
C₁₅H₉N			
2-Cyanophenanthrene (6 g.)	C ₆ H ₅ MgBr (7 ml. C ₆ H ₅ Br)	2-Benzoylphenanthrene (9 g., 85%)	147
2-Cyanophenanthrene (4.3 g.)	2-CH ₃ C ₆ H ₄ MgBr (10 g. C ₆ H ₅ Br)	2- <i>o</i> -Toluyphenanthrene (48%)	148
2-Cyanophenanthrene (5 g.)	2-CH ₃ C ₁₀ H ₆ -1-MgBr (12.5 g. C ₁₁ H ₉ Br) ^c	2-(2-Methyl-1-naphthoyl)phenanthrene (73%)	148
3-Cyanophenanthrene (6 g.)	C ₆ H ₅ MgBr (7 ml. C ₆ H ₅ Br)	3-Benzoylphenanthrene (60%)	147
3-Cyanophenanthrene (4.3 g.)	2-CH ₃ C ₆ H ₄ MgBr (10 g. C ₇ H ₇ Br)	3- <i>o</i> -Toluyphenanthrene (79%)	148

* Range of yields claimed for series of nitriles investigated.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₉N (<i>cont.</i>)			
3-Cyanophenanthrene (5 g.)	2-CH ₃ C ₁₀ H ₆ -1-MgBr (12.5 g. C ₁₁ H ₉ Br)	3-(2-Methyl-1-naphthoyl)phenanthrene (51%)	148
9-Cyanophenanthrene (609 g., 3 moles)	CH ₃ MgI (6 moles CH ₃ I)	9-Acetylphenanthrene (345-390 g., 52-59%)	165
9-Cyanophenanthrene (5.4 g.)	C ₆ H ₅ MgBr (6 g. C ₆ H ₅ Br)	9-Benzoylphenanthrene (3 g. 42%)	79
9-Cyanophenanthrene (1.0 g.)	C ₆ H ₅ MgBr (1.5 g. C ₆ H ₅ Br)	α -9-Anthroyl- α -phenylmethyleimine (1.26 g., 92%)	167
9-Cyanophenanthrene (4.3 g.)	2-CH ₃ C ₆ H ₄ MgBr (10 g. C ₇ H ₇ Br)	9- <i>o</i> -Toluyphenanthrene (83%)	148
9-Cyanophenanthrene (5 g.)	2-CH ₃ C ₁₀ H ₆ -1-MgBr (12.5 g. C ₁₁ H ₉ Br)	9-(2-Methyl-1-naphthoyl)phenanthrene (65%)	148
C₁₅H₁₁N			
C ₆ H ₅ CH=C(C ₆ H ₅)CN	C ₂ H ₅ MgBr	C ₆ H ₅ CH(C ₂ H ₅)CH(C ₆ H ₅)CN; two isomeric products (m. 115°; b. 210-212°/20 mm.)	100
C ₆ H ₅ CH=C(C ₆ H ₅)CN (41 g.)	C ₂ H ₅ MgBr (0.2 mole)	C ₆ H ₅ CH(C ₂ H ₅)C(C ₂ H ₅)(C ₆ H ₅)CN (isomer m. 102-103°, >24.4 g.; isomer m. 93-99°, 2.76 g.)	149
C ₆ H ₅ CH=C(C ₆ H ₅)CN (41 g.)	C ₂ H ₅ MgBr (0.4 mole)	C ₆ H ₅ CH(C ₂ H ₅)C(C ₂ H ₅)(C ₆ H ₅)CN (isomer m. 102-103°, 26.7 g.; isomer m. 93-99°, 2.69 g.)	149
C ₆ H ₅ CH=C(C ₆ H ₅)CN	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH(C ₆ H ₅)CN; C ₆ H ₅ CH=C(C ₆ H ₅)COC ₆ H ₅ (30-40%)	100
(C ₆ H ₅) ₂ C=CHCN	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ C=CHCOC ₆ H ₅ (68%)	100
C₁₅H₁₃N			
C ₆ H ₅ (C ₆ H ₅ CH ₂)CHCN	CH ₃ MgI (4 equiv.)	C ₆ H ₅ (C ₆ H ₅ CH ₂)CHCOCH ₃	50
C ₆ H ₅ (C ₆ H ₅ CH ₂)CHCN	C ₂ H ₅ MgBr (4 equiv.)	C ₆ H ₅ (C ₆ H ₅ CH ₂)CHCOC ₂ H ₅	50
C ₆ H ₅ (2-CH ₃ C ₆ H ₄)CHCN	C ₆ H ₅ MgBr	Recovered nitrile	80

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₃N (<i>cont.</i>)			
C ₆ H ₅ (3-CH ₃ C ₆ H ₄)CHCN (4.3 g.)	C ₆ H ₅ MgBr (15.0 g. C ₆ H ₅ Br)	C ₆ H ₅ (3-CH ₃ C ₆ H ₄)CHCOC ₆ H ₅	80
2-C ₆ H ₅ CH ₂ CH ₂ C ₆ H ₄ CN (18.0 g.)	C ₆ H ₅ MgBr (14.2 ml. C ₆ H ₅ Br)	C ₆ H ₅ COC ₆ H ₄ -2-CH ₂ CH ₂ C ₆ H ₅ (24.0 g.)	162
2-[CH ₃ (C ₆ H ₅)CH]C ₆ H ₄ CN (18.0 g.)	C ₆ H ₅ MgBr (14.2 ml. C ₆ H ₅ Br)	C ₆ H ₅ COC ₆ H ₄ -2-CH(CH ₃)C ₆ H ₅ (21.1 g.)	162
2-C ₆ H ₅ CH ₂ O-3-CH ₃ OC ₆ H ₃ CN (23.9 g.)	C ₂ H ₅ MgBr (10.9 g. C ₂ H ₅ Br)	Recovered nitrile ("much"); 2-C ₂ H ₅ -3-CH ₃ OC ₆ H ₃ CN (2 g.); 2-HO-3-CH ₃ OC ₆ H ₃ COC ₂ H ₅ ("some"); C ₆ H ₅ CH ₂ OH	166
C₁₅H₁₄N₂			
(C ₆ H ₅ CH ₂) ₂ NCN (12 g.)	C ₂ H ₅ MgBr	(C ₆ H ₅ CH ₂) ₂ NC(=NH · HCl)C ₂ H ₅ (15 g., crude)	150
(C ₆ H ₅ CH ₂) ₂ NCN	C ₆ H ₅ MgBr	(C ₆ H ₅ CH ₂) ₂ NC(=NH · HCl)C ₆ H ₅ (70%)	150
(C ₆ H ₅ CH ₂) ₂ NCN	4-CH ₃ C ₆ H ₄ MgBr	(C ₆ H ₅ CH ₂) ₂ NC(=NH · HCl)C ₆ H ₄ -4-CH ₃ (70%)	150
C₁₅H₂₉N			
<i>n</i> -C ₁₄ H ₂₉ CN (493 g.)	CH ₃ MgBr (285 g. CH ₃ Br)	<i>n</i> -C ₁₄ H ₂₉ COCH ₃ (40%)	141
<i>n</i> -C ₁₄ H ₂₉ CN	C ₂ H ₅ MgX	<i>n</i> -C ₁₄ H ₂₉ COC ₂ H ₅ (<i>ca.</i> 65%)	20
<i>n</i> -C ₁₄ H ₂₉ CN	<i>n</i> -C ₃ H ₇ MgX	<i>n</i> -C ₁₄ H ₂₉ CO- <i>n</i> -C ₃ H ₇ (<i>ca.</i> 65%)	20
C₁₆H₁₀N₂			
2-Phenyl-4-cyanoquinoline	C ₂ H ₅ MgBr	2-Phenyl-4-propionylquinoline	151
2-Phenyl-4-cyanoquinoline	C ₆ H ₅ MgBr	2-Phenyl-4-benziminoquinoline	152
2-Phenyl-4-cyanoquinoline	C ₆ H ₅ CH ₂ MgCl	2-Phenyl-4- <i>α</i> -toluylquinoline	151
C₁₆H₁₃NO			
4-CH ₃ OC ₆ H ₄ CH=C(C ₆ H ₅)CN (58.7 g.)	C ₂ H ₅ MgBr (0.35 mole) (+ C ₂ H ₅ I)	4-CH ₃ OC ₆ H ₄ CH(C ₂ H ₅)C(C ₂ H ₅)(C ₆ H ₅)CN (43.7 g.); liquid isomer	149

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₁₄N₂ 9-Cyano-9,10-dimethyl-9,10-dihydroacridine	CH ₃ MgI (2 equiv.)	9,9,10-Trimethyl-9,10-dihydroacridine	98
C₁₆H₁₅N 2-[C ₆ H ₅ (CH ₃) ₂ C]C ₆ H ₄ CN (5.0 g.)	C ₆ H ₅ MgBr (14.2 g. C ₆ H ₅ Br)	2-[C ₆ H ₅ (CH ₃) ₂ C]C ₆ H ₄ C(=NH·HCl)C ₆ H ₅ (4.55 g., 60%)	115
C₁₆H₂₈N₂ [—(CH ₂) ₇ CH] ₇	C ₂ H ₅ MgBr (excess)	[—(CH ₂) ₇ COC ₂ H ₅] ₂ (85%)	132
C₁₆H₃₁N <i>n</i> -C ₁₅ H ₃₁ CN	CH ₃ MgX	<i>n</i> -C ₁₅ H ₃₁ COCH ₃ (ca. 65%)	20
<i>n</i> -C ₁₅ H ₃₁ CN	C ₂ H ₅ MgX	<i>n</i> -C ₁₅ H ₃₁ COC ₂ H ₅ (ca. 65%)	20
<i>n</i> -C ₁₅ H ₃₁ CN	<i>n</i> -C ₄ H ₉ MgBr (sl. excess)	<i>n</i> -C ₁₅ H ₃₁ CO- <i>n</i> -C ₄ H ₉	134
<i>n</i> -C ₁₅ H ₃₁ CN (1.5–2 moles)	C ₆ H ₅ MgBr (sl. excess)	<i>n</i> -C ₁₅ H ₃₁ COC ₆ H ₅ (75–90%)*	163
C₁₇H₉N 4-Cyanofluoranthene	CH ₃ MgI	4-Acetylfluoranthene	156
C₁₇H₁₄N₂ (C ₆ H ₅ CH ₂) ₂ C(CN) ₂ (7.0 g.)	C ₆ H ₅ MgBr (3.5 g. Mg)	(C ₆ H ₅ CH ₂) ₂ CHCN (5.1 g., 80%); (C ₆ H ₅) ₂ C=NH (isolated as benzophenone)	17
(C ₆ H ₅ CH ₂) ₂ C(CN) ₂ (7.0 g.)	C ₆ H ₅ MgBr (3.5 g. Mg)	(C ₆ H ₅ CH ₂) ₂ CHCOC ₆ H ₅ (3.1 g.); (C ₆ H ₅) ₂ CO	17

* Range of yields claimed for series of nitriles investigated.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₁₃NO₂			
4-CH ₃ OC ₆ H ₄ CH=C(C ₆ H ₄ -4-OCH ₃)CN (26.5 g.)	C ₂ H ₅ MgBr (0.2 mole)	4-CH ₃ OC ₆ H ₄ CH(C ₂ H ₅)C(C ₂ H ₅)(C ₆ H ₄ -4-OCH ₃)CN (11.4 g.); liquid isomer	149
C₁₇H₁₇N			
C ₂ H ₅ (C ₆ H ₅)CHCH(C ₆ H ₅)CN (m. 115°)	CH ₃ MgI	C ₂ H ₅ CH(C ₆ H ₅)CH(C ₆ H ₅)COCH ₃ (two isomers; m. 56°, m. 116°)	100
C ₂ H ₅ (C ₆ H ₅)CHCH(C ₆ H ₅)CN (either isomer)	C ₆ H ₅ MgBr	C ₂ H ₅ CH(C ₆ H ₅)CH(C ₆ H ₅)COC ₆ H ₅ (two isomers; m. 92°, m. 170°)	100
<i>i</i> -C ₃ H ₇ (C ₆ H ₅) ₂ CCN	C ₆ H ₅ MgBr	<i>i</i> -C ₃ H ₇ (C ₆ H ₅) ₂ CCOC ₆ H ₅	65
<i>i</i> -C ₃ H ₇ (C ₆ H ₅) ₂ CCN	C ₆ H ₅ MgBr (3 equiv.) (+ HBr)	<i>i</i> -C ₃ H ₇ (C ₆ H ₅) ₂ CC(=NH·HBr)C ₆ H ₅ (30%)	66
(C ₂ H ₅)(C ₆ H ₅)(C ₆ H ₅ CH ₂)CCN	C ₆ H ₅ MgBr	(C ₂ H ₅)(C ₆ H ₅)(C ₆ H ₅ CH ₂)CCOC ₆ H ₅	65
C ₂ H ₅ (C ₆ H ₅)(C ₆ H ₅ CH ₂)CCN	C ₆ H ₅ MgBr (1.25 equiv.) (+ HBr)	C ₂ H ₅ (C ₆ H ₅)(C ₆ H ₅ CH ₂)CC(=NH·HBr)C ₆ H ₅ (65-70%)	66
C₁₆H₁₃NO			
2-β-C ₁₀ H ₇ -3-CH ₃ OC ₆ H ₃ CN (13 g.)	CH ₃ MgI	2-β-C ₁₀ H ₇ -3-CH ₃ OC ₆ H ₃ COCH ₃ (3.5 g.)	101
C₁₆H₁₄N₂			
α-Truxillic acid dinitrile	C ₆ H ₅ MgBr	α- and γ-1,3-Diphenyl-2,4-dibenzoyl-cyclobutane	169
δ-Truxinic acid dinitrile	C ₆ H ₅ MgBr	δ-1,2-Diphenyl-3,4-dibenzoylcyclobutane	169
Epitruxillic acid dinitrile	C ₆ H ₅ MgBr	No appreciable reaction	169
Neotruxillic acid dinitrile	C ₆ H ₅ MgBr	No appreciable reaction	169
C₁₈H₁₇NO			
2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -2-CN (2.6 g.)	CH ₃ MgI (7.1 g. CH ₃ I)	1,1-Dimethyl-3-durylpseudoisindole (2.6 g., 83%)	193

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₈H₁₇NO (<i>cont.</i>)			
2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -2-CN (7.9 g.)	H ₂ C=CHCH ₂ MgBr (0.15 mole)	1,1-Diallyl-3-durypseudoisoindole (7.5 g., 76%)	193
2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -2-CN (2.6 g.)	C ₆ H ₅ MgBr (15.7 g. C ₆ H ₅ Br)	1,1-Diphenyl-3-durypseudoisoindole (2.1 g., 51%)	193
2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -2-CN (5.2 g.)	4-CH ₃ C ₆ H ₄ MgBr (17.0 g. C ₇ H ₇ Br)	1,1-Di- <i>p</i> -tolyl-3-durypseudoisoindole (2.6 g., 31%)	193
2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -2-CN (7.9 g.)	4-CH ₃ OC ₆ H ₄ MgBr (28.0 g. C ₇ H ₇ BrO)	1,1-Di- <i>p</i> -anisyl-3-durypseudoisoindole (5.0 g., 36%)	193
2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -2-CN (7.9 g.)	1-C ₁₀ H ₇ MgBr (20.7 g. C ₁₀ H ₇ Br)	1,1-Di- α -naphthyl-3-durypseudo- isoindole (9.3 g., 65%)	193
2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -3-CN (1.3 g.)	<i>s</i> -C ₄ H ₉ MgBr (3.4 g. C ₄ H ₉ Br)	2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -3-CO- <i>s</i> -C ₄ H ₉ (0.5 g., 31%)	193
2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -3-CN (1.3 g.)	C ₆ H ₅ CH ₂ MgCl (3.2 g. C ₇ H ₇ Cl)	2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -3-COCH ₂ C ₆ H ₅ (0.95 g., 53%)	193
2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -4-CN (2.6 g.)	CH ₃ MgI (7.1 g. CH ₃ I)	Recovered nitrile (<i>ca.</i> 50%); 2,3,5,6- (CH ₃) ₄ C ₆ HCOC ₆ H ₄ -4-CH ₃ (14%)	193
2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -4-CN (1.3 g.)	C ₆ H ₅ CH ₂ MgCl (3.2 g. C ₇ H ₇ Cl)	2,3,5,6-(CH ₃) ₄ C ₆ HCOC ₆ H ₄ -4-CH ₂ C ₆ H ₅ (44%)	193
2-(1,2,3,4-Tetrahydro-2-naphthyl)- 3-methoxybenzonitrile (9.3 g.)	CH ₃ MgI (8 g. CH ₃ I)	2-(1,2,3,4-Tetrahydro-2-naphthyl)-3- methoxyacetophenone (5.6 g.)	101
C₁₈H₁₇NO₂			
4-CH ₃ OC ₆ H ₄ COCH(C ₂ H ₅)C ₆ H ₄ -4-CN (5 g.)	CH ₃ MgBr (5 g. Mg)	4-CH ₃ OC ₆ H ₃ C(OH)(CH ₃)CH(C ₂ H ₅)C ₆ H ₄ - 4-COCH ₃ (4 g.)	154
C₁₈H₂₀N₂			
(CH ₃) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN	CH ₃ MgX	(CH ₃) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ COCH ₃	160
(CH ₃) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN	C ₂ H ₅ MgBr	(CH ₃) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ COC ₂ H ₅ (78%)	160, 158

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₈H₂₀N₂ (cont.)			
D- or L-(CH ₃) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN	C ₂ H ₅ MgBr	D- or L-(CH ₃) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ COC ₂ H ₅	169
(CH ₃) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN	<i>n</i> -C ₃ H ₇ MgI	(CH ₃) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CO- <i>n</i> -C ₃ H ₇	158
(CH ₃) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN	<i>i</i> -C ₃ H ₇ MgBr	(CH ₃) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CO- <i>i</i> -C ₃ H ₇	158
(CH ₃) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂	C ₆ H ₅ MgX	(CH ₃) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ COC ₆ H ₅ (89%)	160
C₁₈H₃₅N			
<i>n</i> -C ₁₇ H ₃₅ CN (1.5-2 moles)	C ₆ H ₅ MgBr (sl. excess)	<i>n</i> -C ₁₇ H ₃₅ COC ₆ H ₅ (75-90%)*	163
<i>n</i> -C ₁₇ H ₃₅ CN (530 g.)	C ₆ H ₅ CH ₂ CH ₂ MgBr (420 g. C ₈ H ₉ Br)	<i>n</i> -C ₁₇ H ₃₅ COCH ₂ CH ₂ C ₆ H ₅ (394 g., 53%)	153
<i>n</i> -C ₁₇ H ₃₅ CN (531 g.)	(CH ₂) ₄ CH(CH ₂) ₃ MgBr (440 g. C ₈ H ₁₅ Br)	<i>n</i> -C ₁₇ H ₃₅ CO(CH ₂) ₃ CH(CH ₂) ₄ (371 g., 49%)	153
<i>n</i> -C ₁₇ H ₃₅ CN (755.5 g.)	<i>n</i> -C ₈ H ₁₇ MgBr (772 g. C ₈ H ₁₇ Br)	<i>n</i> -C ₁₇ H ₃₅ CO- <i>n</i> -C ₈ H ₁₇ (920 g., 69%)	153
C₁₉H₂₁N			
C ₂ H ₅ (C ₆ H ₅)CHC(C ₂ H ₅)(C ₆ H ₅)CN	CH ₃ MgI	Recovered nitrile	100
C ₂ H ₅ (C ₆ H ₅)CHC(C ₂ H ₅)(C ₆ H ₅)CN	C ₆ H ₅ MgBr	Recovered nitrile	100
C₁₉H₂₂N₂			
(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ CN (5 g.)	CH ₃ MgI (7.7 g. CH ₃ I)	(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ COCH ₃	158
(-)-(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ CN	C ₂ H ₅ MgBr	(-)-(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ COC ₂ H ₅	158
(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ CN	C ₂ H ₅ MgBr	(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ C(=NH)C ₂ H ₅	170,171,172
(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ CN (11.1 g.)	C ₂ H ₅ MgI (12.5 g. C ₂ H ₅ I)	(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ COC ₂ H ₅ (83%)	161
(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ CN	<i>n</i> -C ₃ H ₇ MgI	(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ CO- <i>n</i> -C ₃ H ₇	158
(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ CN	<i>i</i> -C ₃ H ₇ MgBr	(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ CO- <i>i</i> -C ₃ H ₇	158

* Range of yields claimed for series of nitriles investigated.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₉H₂₂N₂ (cont.)			
(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ CN	<i>n</i> -C ₄ H ₉ MgI	(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ CO- <i>n</i> -C ₄ H ₉	158
(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ CN	C ₆ H ₅ MgBr	(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ COC ₆ H ₅	158
(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ CN	C ₆ H ₅ CH ₂ MgBr	(CH ₃) ₂ NCH(CH ₃)CH ₂ C(C ₆ H ₅) ₂ COCH ₂ C ₆ H ₅	158
(CH ₃) ₂ NCH ₂ CH(CH ₃)C(C ₆ H ₅) ₂ CN (150 g.)	C ₂ H ₅ MgBr (132 g. C ₂ H ₅ Br)	(CH ₃) ₂ NCH ₂ CH(CH ₃)C(C ₆ H ₅) ₂ C(=NH)C ₂ H ₅ (147 g., crude)	158, 170, 171, 172
(CH ₃) ₂ NCH ₂ CH(CH ₃)C(C ₆ H ₅) ₂ CN (16.6 g.)	<i>n</i> -C ₃ H ₇ MgBr	HCl · (CH ₃) ₂ NCH ₂ CH(CH ₃)C(C ₆ H ₅) ₂ CO- <i>n</i> -C ₃ H ₇ (3.75 g.)	158
(CH ₃) ₂ NCH ₂ CH(CH ₃)C(C ₆ H ₅) ₂ CN	<i>i</i> -C ₃ H ₇ MgBr (5 equiv.)	(CH ₃) ₂ NCH ₂ CH(CH ₃)C(C ₆ H ₅) ₂ CO- <i>i</i> -C ₃ H ₇	158
(CH ₃) ₂ N(CH ₂) ₃ C(C ₆ H ₅) ₂ CN (20 g.)	C ₂ H ₅ MgBr (22 g. C ₂ H ₅ Br)	(CH ₃) ₂ N(CH ₂) ₃ C(C ₆ H ₅) ₂ C(=NH)C ₂ H ₅	170
C₂₀H₁₅N			
(C ₆ H ₅) ₃ CCN	C ₆ H ₅ CH ₂ MgCl (4 equiv.)	(C ₆ H ₅) ₃ CH (70%); (C ₆ H ₅ CH ₂ -) ₂	66
C₂₀H₂₂N₂			
(CH ₂) ₄ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN	C ₂ H ₅ MgX	(CH ₂) ₄ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN (68%)	160
C₂₀H₂₂N₂O			
2,2-Diphenyl-4-(4-morpholinyl)butyronitrile	C ₂ H ₅ MgX	4,4-Diphenyl-6-(4-morpholinyl)-3-hexanone	160
C₂₀H₂₃NO₂			
4-CH ₃ OC ₆ H ₄ C(OH)(C ₂ H ₅)- CH(C ₂ H ₅)C ₆ H ₄ -4-CN (5 g.)	CH ₃ MgBr (2.5 g. Mg)	4-CH ₃ OC ₆ H ₄ C(OH)(C ₂ H ₅)CH(C ₂ H ₅)C ₆ H ₄ - 4-COCH ₃ (4.5 g.)	154
C₂₀H₂₄N₂			
(CH ₃) ₂ NCH(C ₂ H ₅)CH ₂ C(C ₆ H ₅) ₂ CN	C ¹⁴ H ₃ CH ₂ MgBr	(CH ₃) ₂ NCH(C ₂ H ₅)CH ₂ C(C ₆ H ₅) ₂ COCH ₂ C ¹⁴ H ₃	159
(CH ₃) ₂ NCH(C ₂ H ₅)CH ₂ C(C ₆ H ₅) ₂ CN	CH ₃ C ¹⁴ H ₂ MgBr	(CH ₃) ₂ NCH(C ₂ H ₅)CH ₂ C(C ₆ H ₅) ₂ C ¹⁴ CH ₂ CH ₃	159
(C ₂ H ₅) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN	C ₂ H ₅ MgX	(C ₂ H ₅) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ COCH ₃	160

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₁H₁₇N			
(C ₆ H ₅) ₃ CCH ₂ CN (28.3 g.)	CH ₃ MgI (71.0 g. CH ₃ I)	CH ₃ [(C ₆ H ₅) ₃ CCH ₂]C=NH · HCl (20.5 g.)	155
(C ₆ H ₅) ₃ CCH ₂ CN (28.3 g.)	C ₂ H ₅ MgBr (65.4 g. C ₂ H ₅ Br)	C ₂ H ₅ [(C ₆ H ₅) ₃ CCH ₂]C=NH · HCl (30.9 g., 88%)	155
(C ₆ H ₅) ₃ CCH ₂ CN (14.0 g.)	C ₆ H ₅ MgBr (39.2 g. C ₆ H ₅ Br)	C ₆ H ₅ [(C ₆ H ₅) ₃ CCH ₂]C=NH · HCl (12.8 g., 70%)	155
C ₆ H ₅ CH ₂ (C ₆ H ₅) ₂ CCN	C ₆ H ₅ MgBr	Recovered nitrile (quant.)	65
C ₆ H ₅ CH ₂ (C ₆ H ₅) ₂ CCN	C ₆ H ₅ CH ₂ MgCl (3-5 equiv.)	C ₆ H ₅ CH ₂ (C ₆ H ₅) ₂ CH	66
C₂₁H₂₃NO₂			
3-Acetoxy-17-cyano-1,3,5,16-estratetraene	CH ₃ MgBr (excess)	3-Hydroxy-17-acetyl-1,3,5,16-estratetraene	173
C₂₁H₂₄N₂			
(CH ₂) ₅ NCH ₂ CH ₂ C(C ₆ H ₅) ₂ CN	CH ₃ MgI	(CH ₂) ₅ NCH ₂ CH ₂ C(C ₆ H ₅) ₂ COCH ₃	158
(CH ₂) ₅ NCH ₂ CH ₂ C(C ₆ H ₅) ₂ CN	C ₂ H ₅ MgX	(CH ₂) ₅ NCH ₂ CH ₂ C(C ₆ H ₅) ₂ COC ₂ H ₅ (74%)	160,158
(CH ₂) ₅ NCH ₂ CH ₂ C(C ₆ H ₅) ₂ CN	<i>n</i> -C ₃ H ₇ MgI	(CH ₂) ₅ NCH ₂ CH ₂ C(C ₆ H ₅) ₂ CO- <i>n</i> -C ₃ H ₇	158
(CH ₂) ₅ NCH ₂ CH ₂ C(C ₆ H ₅) ₂ CN	C ₆ H ₅ MgBr	(CH ₂) ₅ NCH ₂ CH ₂ C(C ₆ H ₅) ₂ COC ₆ H ₅	158
2,2-Diphenyl-4-(2-methyl-4-morpholinyl)butyronitrile	C ₂ H ₅ MgX	4,4-Diphenyl-6-(2-methyl-4-morpholinyl)-3-hexanone (65%)	160
2-Phenyl-2- <i>o</i> -tolyl-4-(4-morpholinyl)butyronitrile	C ₂ H ₅ MgX	4-Phenyl-4- <i>o</i> -tolyl-6-(4-morpholinyl)-3-hexanone	160
2-Phenyl-2- <i>p</i> -tolyl-4-(4-morpholinyl)butyronitrile	C ₂ H ₅ MgX	4-Phenyl-4- <i>p</i> -tolyl-6-(4-morpholinyl)-3-hexanone (61%)	160
2,2-Diphenyl-5-(4-morpholinyl)valeronitrile	C ₂ H ₅ MgX	4,4-Diphenyl-7-(4-morpholinyl)-3-heptanone (74%)	160

TABLE X-I (Continued)

<u>Cyano Comp'd</u>		<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₁H₂₄N₂O				
2,2-Diphenyl-4-(4-morpholinyl)valeronitrile	C ₂ H ₅ MgI		4,4-Diphenyl-6-(4-morpholinyl)-3-heptanone (73%)	161,210
2,2-Diphenyl-3-methyl-4-(4-morpholinyl)butyronitrile (3.2 g.)	C ₂ H ₅ MgI (3.2 g. C ₂ H ₅ I)		3-Imino-4,4-diphenyl-6-(4-morpholinyl)-5-methylhexane (3.36 g., crude)	161
C₂₁H₂₆N₂				
(C ₂ H ₅) ₂ N(CH ₂) ₃ C(C ₆ H ₅) ₂ CN	C ₂ H ₅ MgX		(C ₂ H ₅) ₂ N(CH ₂) ₃ C(C ₆ H ₅) ₂ COC ₂ H ₅ (82%)	106
C₂₂H₂₆N₂				
2,2-Diphenyl-4-(2-methyl-1-piperidyl)butyronitrile	C ₂ H ₅ MgX		4,4-Diphenyl-6-(2-methyl-1-piperidyl)-3-hexanone (60%)	160
2,2-Diphenyl-4-(3-methyl-1-piperidyl)butyronitrile	C ₂ H ₅ MgX		4,4-Diphenyl-6-(3-methyl-1-piperidyl)-3-hexanone (60%)	160
2,2-Diphenyl-4-(4-methyl-1-piperidyl)butyronitrile	C ₂ H ₅ MgX		4,4-Diphenyl-6-(4-methyl-1-piperidyl)-3-hexanone (53%)	160
C₂₂H₂₆N₂O				
2,2-Diphenyl-4-(2,6-dimethyl-4-morpholinyl)butyronitrile	C ₂ H ₅ MgX		4,4-Diphenyl-6-(2,6-dimethyl-4-morpholinyl)-3-hexanone (32%)	160
2,2-Diphenyl-6-(4-morpholinyl)capronitrile	C ₂ H ₅ MgX		4,4-Diphenyl-8-(4-morpholinyl)-3-octanone (79%)	160
C₂₂H₂₈N₂				
(<i>n</i> -C ₃ H ₇) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN	C ₂ H ₅ MgX		(<i>n</i> -C ₃ H ₇) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ COC ₂ H ₅ (65%)	160
C₂₂H₂₈NO₂				
3-Acetoxy-17-cyano-5,16-androstadiene (1.8 g.)	CH ₃ MgBr* (5 g. Mg)		5,16-Pregnadien-3-ol-20-one (1.26 g., 75%)	139

* CH₃MgI gives poorer yields. Forty-eight hours reflux.

TABLE X-I (Continued)

<u>Cyano Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₂H₂₉NO₂ (<i>cont.</i>)			
3-Acetoxy-17-cyano-5,16-androstadiene*	CH ₃ MgBr	17-Cyano-5,16-androstadien-3-ol	139
C₂₂H₅₁NO₂			
3-Acetoxy-17-cyano-16-androstene (900 mg.)	CH ₃ MgBr (2.5 g. Mg)	<i>epi-allo</i> -16-Pregnen-3-ol-20-one (450 mg.)	157
C₂₃H₂₈N₂			
2,2-Diphenyl-4-(2,6-dimethyl-1-piperidyl)butyronitrile	C ₂ H ₅ MgX	4,4-Diphenyl-6-(2,6-dimethyl-1-piperidyl)-3-hexanone (69%)	160
C₂₄H₁₆N₂			
2,4,6-Triphenyl-3-cyanopyridine (11.6 g., 0.035 mole)	C ₆ H ₅ MgBr (0.25 mole)	2,4,6-Triphenyl-3-phenylketimino-pyridine (72%)	216
C₂₄H₂₄N₂			
CH ₃ (C ₆ H ₅ CH ₂)N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN	C ₂ H ₅ MgX	CH ₃ (C ₆ H ₅ CH ₂)N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN (60%)	160
C₂₄H₃₂N₂			
(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN	C ₂ H ₅ MgX	(<i>n</i> -C ₄ H ₉) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ COC ₂ H ₅ (70%)	160
C₂₈H₂₆N₂			
(C ₆ H ₅ CH ₂) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ CN	C ₂ H ₅ MgX	(C ₆ H ₅ CH ₂) ₂ N(CH ₂) ₂ C(C ₆ H ₅) ₂ COC ₂ H ₅ (54%)	160

* Short reaction time.

REFERENCES FOR TABLE X-I

- (1) Blaise, *Compt. rend.*, 132, 38-41 (1901); *Chem. Zentr.*, 1901,I, 298.
- (2) Mousseron and Winternitz, *Compt. rend.*, 217, 428-30 (1943); *Chem. Abstr.*, 39, 2054 (1945).
- (3) Mathus, *Bull. soc. chim. Belg.*, 34, 285-9 (1925).
- (4) Tröger and Beck, *J. prakt. Chem.*, [2], 87, 289-311 (1913).
- (5) von Braun, Deutsch, and Schmatloch, *Ber.*, 45, 1246-63 (1912).
- (6) Bruylants, *Bull. acad. roy. Belg.*, [5], 8, 7-23 (1922); *Chem. Zentr.*, 1923,I, 85.
- (7) Mignonac and Hoffman, *Compt. rend.*, 191, 718-20 (1930).
- (8) Bary, *Bull. soc. chim. Belg.*, 31, 397-410 (1922).
- (9) Shriner and Turner, *J. Am. Chem. Soc.*, 52, 1267-9 (1930).
- (10) Whitmore and Sloat, *J. Am. Chem. Soc.*, 64, 2968-70 (1942).
- (11) Majima and Hoshino, *Ber.*, 58B, 2042-6 (1925).
- (12) Lipp and Quaadvlieg, *Ber.*, 62B, 2311-22 (1929).
- (13) Mousseron, Winternitz, Jullien, and Jacquier, *Bull. soc. chim.*, [5], 15, 79-84 (1948).
- (14) Challenger, Clapham, and Emmott, *J. Inst. Petroleum*, 34, 922-9 (1948); *Chem. Abstr.*, 43, 4666 (1949).
- (15) Cauquil and Barrera, *Compt. rend.*, 226, 1282-3 (1948); *Chem. Abstr.*, 42, 5888 (1948).
- (16) Yarnall and Wallis, *J. Org. Chem.*, 4, 284-8 (1939).
- (17) Erickson and Barnett, *J. Am. Chem. Soc.*, 57, 560-2 (1935).
- (18) Thomson and Stevens, *J. Chem. Soc.*, 1932, 2607-12.
- (19) Baerts, *Bull. soc. chim. Belg.*, 31, 184-92 (1922).
- (20) Oldham and Ubbelohde, *J. Chem. Soc.*, 1939, 201-2.
- (21) Gauthier, *Ann. chim.*, [8], 16, 289-358 (1909).
- (22) Allen and Henze, *J. Am. Chem. Soc.*, 61, 1790-4 (1939).
- (23) Paul, *Bull. soc. chim.*, [4], 45, 152-4 (1929).
- (24) Gauthier, *Compt. rend.*, 152, 1100-2 (1911); *Chem. Zentr.*, 1911,I, 1809.
- (25) Vuylsteke, *Bull. acad. roy. Belg.*, [5], 12, 535-44 (1926); *Chem. Zentr.*, 1927,I, 888; *Chem. Abstr.*, 21, 1108 (1927).
- (26) Bruylants and Gevaerts, *Bull. acad. roy. Belg.*, [5], 9, 27-37 (1923); *Chem. Zentr.*, 1923,III, 1263.
- (27) Bruylants and Mathus, *Bull. acad. roy. Belg.*, [5], 11, 636-53 (1925); *Chem. Zentr.*, 1926,I, 3145.
- (28) Bruylants, *Bull. acad. roy. Belg.*, 1908, 1011-84; *Chem. Zentr.*, 1909,I, 1859.
- (29) Bruylants, *Bull. soc. chim. Belg.*, 36, 519-32 (1927).
- (30) Michiels, *Bull. acad. roy. Belg.*, 1912, 10-34; *Chem. Zentr.*, 1912,I, 1105.
- (31) Lipp, Buchkremer, and Seeles, *Ann.*, 499, 1-25 (1932).
- (32) Cloke, *J. Am. Chem. Soc.*, 51, 1174-87 (1929).
- (33) Cloke, Baer, Robbins, and Smith, *J. Am. Chem. Soc.*, 67, 2155-8 (1945).
- (34) Lachmann, Dissertation, Rensselaer Pol. Inst., as cited by Cloke *et al.* (33), footnote, p. 2156.
- (35) Bruylants, *Bull. acad. roy. Belg.*, [5], 10, 392-5 (1924); *Chem. Zentr.*, 1924,II, 2457.
- (36) McKenzie and Duff, *Ber.*, 60B, 1335-41 (1927).
- (37) de Boosere, *Bull. soc. chim. Belg.*, 32, 26-51 (1923).
- (38) Craig, Bulbrook, and Hixon, *J. Am. Chem. Soc.*, 53, 1831-5 (1931).
- (39) Starr, Bulbrook, and Hixon, *J. Am. Chem. Soc.*, 54, 3971-6 (1932).
- (40) Lipp and Seeles, *Ber.*, 62B, 2456-8 (1929).
- (41) Kirchner and Johns, *J. Am. Chem. Soc.*, 62, 2183-4 (1940).
- (42) Wallace and Henze, *J. Am. Chem. Soc.*, 64, 2882 (1942).

- (43) Craig, *J. Am. Chem. Soc.*, 56, 1144-7 (1934).
- (44) Baerts, *Bull. soc. chim. Belg.*, 31, 421-6 (1922).
- (45) Blaise, *Compt. rend.*, 133, 1217-8 (1901); *Chem. Zentr.*, 1902,I, 299.
- (46) Sommelet, *Ann. chim.*, [8], 9, 484-574 (1906).
- (47) Béhal and Sommelet, *Compt. rend.*, 138, 89-92 (1904); *Chem. Zentr.*, 1904,I, 504.
- (48) Henze, U. S. Patent 2,460,747; *Chem. Abstr.*, 43, P3452 (1949).
- (49) Henze, Allen, and Leslie, *J. Org. Chem.*, 7, 326-53 (1942).
- (50) Lévy and Jullien, *Bull. soc. chim.*, [4], 45, 941-50 (1929).
- (51) Bruylants, *Bull. acad. roy. Belg.*, [5], 7, 252-9 (1921); *Chem. Zentr.*, 1921,III, 1349.
- (52) Blaise, *Compt. rend.*, 173, 313-5 (1921).
- (53) Bruylants, *Bull. soc. chim. Belg.*, 32, 307-10 (1923).
- (54) Bruylants and Dewael, *Bull. acad. roy. Belg.*, [5], 12, 464-76 (1926); *Chem. Zentr.*, 1927,I, 887.
- (55) Breckpot, *Bull. soc. chim. Belg.*, 32, 386-97 (1923).
- (56) Asahina and Murayama, *Arch. Pharm.*, 252, 435-48 (1914); *Chem. Zentr.*, 1914,II, 1196.
- (57) Lemaire, *Rec. trav. chim.*, 29, 22-84 (1910); *Bull. acad. roy. Belg.*, 1909, 83-159; *Chem. Abstr.*, 4, 1483 (1910).
- (58) Mukherjee, *J. Indian Chem. Soc.*, 25, 155-64 (1948); *Chem. Abstr.*, 43, 2605 (1949).
- (59) Hauser, Humphlett, and Weiss, *J. Am. Chem. Soc.*, 70, 426 (1948).
- (60) Hauser and Humphlett, *J. Org. Chem.*, 15, 359-66 (1950).
- (61) Blaise, *Compt. rend.*, 132, 978-80 (1901); *Chem. Zentr.*, 1901,I, 1195.
- (62) Mavrodin, *Compt. rend.*, 188, 1504-6 (1929).
- (63) Theunis, *Bull. acad. roy. Belg.*, [5], 12, 785-96 (1926); *Chem. Zentr.*, 1927,I, 889.
- (64) Bourgom, *Bull. soc. chim. Belg.*, 33, 101-15 (1924).
- (65) Ramart-Lucas and Salmon-Legagneur, *Compt. rend.*, 184, 102-4 (1927).
- (66) Ramart-Lucas and Salmon-Legagneur, *Bull. soc. chim.*, [4], 43, 321-9 (1928).
- (67) Asahina and Terasaka, *J. Pharm. Soc. Japan*, 1923, No. 494, 19-21; *Chem. Zentr.*, 1923,III, 434.
- (68) Breckpot, *Bull. soc. chim. Belg.*, 33, 490-4 (1924).
- (69) Guerden, *Bull. acad. roy. Belg.*, [5], 11, 701-10 (1925); *Chem. Zentr.*, 1926,I, 3146.
- (70) Velghe, *Bull. acad. roy. Belg.*, [5], 11, 301-8 (1925); *Chem. Zentr.*, 1926,I, 875.
- (71) Bachmann, *J. Am. Chem. Soc.*, 54, 1969-74 (1932).
- (72) Fieser and Seligman, *J. Am. Chem. Soc.*, 61, 136-42 (1939).
- (73) Ectors, *Bull. soc. chim. Belg.*, 33, 146-59 (1924).
- (74) Ectors, *Bull. acad. roy. Belg.*, [5], 9, 501-18 (1923); *Chem. Zentr.*, 1924,I, 913.
- (75) Moureu and Mignonac, *Ann. chim.*, [9], 14, 322-59 (1920).
- (76) Moureu and Mignonac, *Compt. rend.*, 156, 1801-6 (1913); *Chem. Zentr.*, 1913,II, 497.
- (77) Ectors, *Bull. acad. roy. Belg.*, [5], 10, 347-52 (1924); *Chem. Zentr.*, 1924,II, 2463.
- (78) Gilman, St. John, St. John, and Lichtenwalter, *Rec. trav. chim.*, 55, 577-85 (1936).
- (79) Bachmann, *J. Am. Chem. Soc.*, 56, 1363-7 (1934).
- (80) Roger and McKay, *J. Chem. Soc.*, 1933, 332-6.
- (81) Newman and McCleary, *J. Am. Chem. Soc.*, 63, 1537-41 (1941).

- (82) Busch and Hobein, *Ber.*, 40, 4296-9 (1907).
(83) Bruylants, *Bull. acad. roy. Belg.*, [5], 11, 261-80 (1925); *Chem. Zentr.*, 1926,I, 874.
(84) Weiss and Schlesinger, *Monatsh.*, 48, 451-7 (1927).
(85) Weiss and Freund, *Monatsh.*, 45, 105-14 (1924).
(86) de Coster, *Bull. acad. roy. Belg.*, [5], 11, 661-5 (1925).
(87) Adams, Bramlet, and Tendick, *J. Am. Chem. Soc.*, 42, 2369-74 (1920).
(88) Smith, *Ber.*, 71B, 634-43 (1938).
(89) Stevens, *J. Am. Chem. Soc.*, 61, 1714-6 (1939).
(90) Rondou, *Bull. soc. chim. Belg.*, 31, 231-41 (1922).
(91) Jaspers, *Bull. soc. chim. Belg.*, 34, 182-7 (1925).
(92) Turner, *J. Chem. Soc.*, 107, 1459-64 (1915).
(93) Bachmann and Ferguson, *J. Am. Chem. Soc.*, 56, 2081-4 (1934).
(94) Bailar, *J. Am. Chem. Soc.*, 52, 3596-603 (1930).
(95) Gilman and Lichtenwalter, *Rec. trav. chim.*, 55, 561-3 (1936).
(96) Smith, *Ber.*, 64B, 427-34 (1931).
(97) Tiffeneau and Lévy, *Bull. soc. chim.*, [4], 33, 735-59 (1923).
(98) Stevens, Cowan, and MacKinnon, *J. Chem. Soc.*, 1931, 2568-72.
(99) Mavrodin, *Compt. rend.*, 191, 1064-6 (1930).
(100) Kohler, *Am. Chem. J.*, 35, 386-404 (1906).
(101) Richtzenhain and Miedreich, *Chem. Ber.*, 81, 92-7 (1948).
(102) Rehberg and Henze, *J. Am. Chem. Soc.*, 63, 2785-9 (1941).
(103) Mavrodin, *Bul. soc. chim. România*, 15, 99-106 (1933); *Chem. Abstr.*, 28, 3396 (1934).
(104) Ruggli and Businger, *Helv. Chim. Acta*, 24, 1112-26 (1941).
(105) Haller, *J. Am. Chem. Soc.*, 55, 3032-5 (1933).
(106) Haller and Schaffer, *J. Am. Chem. Soc.*, 61, 2175-7 (1939).
(107) Pfeiffer and Simons, *J. prakt. Chem.*, [2], 160, 83-94 (1942).
(108) Fuson, Ulliot, Stedman, and Tawney, *J. Am. Chem. Soc.*, 60, 1447-50 (1938).
(109) Mavrodin, *Compt. rend.*, 192, 363-5 (1931).
(110) Kaufmann, Peyer, and Kunkler, *Ber.*, 45, 3090-8 (1912).
(111) Rabe and Pasternack, *Ber.*, 46, 1026-32 (1932).
(112) Kaufman, Dandliker, and Burkhardt, *Ber.*, 46, 2929-35 (1913).
(113) Padbury and Lindwall, *J. Am. Chem. Soc.*, 67, 1268-70 (1945).
(114) Sabetay, *Bull. soc. chim.*, [4], 45, 534-40 (1929).
(115) Bradsher and Smith, *J. Am. Chem. Soc.*, 65, 1643-5 (1943).
(116) Cagniant and Deluzarche, *Compt. rend.*, 223, 677-9 (1946); *Chem. Abstr.*, 41, 1669 (1947).
(117) Newman and Orchin, *J. Am. Chem. Soc.*, 60, 586-9 (1938).
(118) Newman and Wise, *J. Am. Chem. Soc.*, 63, 2109-11 (1941).
(119) Tschitschibabin and Korjagin, *J. Russ. Phys.-Chem. Soc.*, 45, 1823-9 (1914); *Chem. Abstr.*, 8, 912 (1914); *Chem. Zentr.*, 1914,I, 1658.
(120) Haworth, Mavin, and Sheldrick, *J. Chem. Soc.*, 1934, 454-61.
(121) Newman, *J. Am. Chem. Soc.*, 60, 1368-70 (1938).
(122) Strukow, *Khim. Farm. Prom.*, 1934, No. 3, 13-14; *Chem. Abstr.*, 29, 1821 (1935).
(123) Murray and Cloke, *J. Am. Chem. Soc.*, 68, 126-9 (1946).
(124) Haworth and Mavin, *J. Chem. Soc.*, 1932, 2720-3.
(125) Plancher and Guimelli, *Atti accad. Lincei*, [5], 18,II, 393-7 (1910); *Chem. Zentr.*, 1910,I, 451.
(126) Cagniant and Cagniant, *Bull. soc. chim.*, [5], 15, 1012-4 (1948).
(127) Weissberger and Glass, *J. Am. Chem. Soc.*, 64, 1724-7 (1942).
(128) Adams, Harfenist, and Loewe, *J. Am. Chem. Soc.*, 71, 1624-8 (1949).

- (129) Haworth and Sheldrick, *J. Chem. Soc.*, 1934, 1950-2.
- (130) Kaufman, Kunkler, and Peyer, *Ber.*, 46, 57-64 (1913).
- (131) Kohler and Reimer, *Am. Chem. J.*, 33, 335-56 (1908).
- (132) Meyer and Streuch, *Helv. Chim. Acta*, 20, 1179-83 (1937).
- (133) Polgar and Robinson, *J. Chem. Soc.*, 1945, 389-95.
- (134) Whitmore, Sutherland, and Cosby, *J. Am. Chem. Soc.*, 64, 1360-4 (1942).
- (135) Clarkson and Gomberg, *J. Am. Chem. Soc.*, 52, 2881-91 (1930).
- (136) Maxim and Aldea, *Bull. soc. chim.*, [5], 2, 582-91 (1935).
- (137) Kühling and Frank, *Ber.*, 42, 3952-8 (1909).
- (138) Bruce and Todd, *J. Am. Chem. Soc.*, 60, 1447-50 (1938).
- (139) Butenandt and Schmidt-Thomé, *Ber.*, 72B, 182-7 (1939).
- (140) Christiaen, *Bull. soc. chim. Belg.*, 33, 483-90 (1924).
- (141) Asinger and Eckholdt, *Ber.*, 76B, 579-84 (1943).
- (142) Dufraisse and Mathieu, *Bull. soc. chim.*, [5], 14, 302-6 (1947).
- (143) Seidel, *Ber.*, 61B, 2267-76 (1928).
- (144) Cloke and Leary, *J. Am. Chem. Soc.*, 67, 1249-51 (1945).
- (145) MacLeod, *Am. Chem. J.*, 44, 331-52 (1910).
- (146) Vasiliu and Radvan, *Bul. soc. chim. România*, 20A, 243-50 (1938); *Chem. Abstr.*, 34, 4058 (1940).
- (147) Bachmann, *J. Am. Chem. Soc.*, 57, 555-9 (1935).
- (148) Bachmann, *J. Am. Chem. Soc.*, 57, 1130-1 (1935).
- (149) Wawzonek, *J. Am. Chem. Soc.*, 68, 1157-9 (1946).
- (150) Adams and Beebe, *J. Am. Chem. Soc.*, 38, 2768-72 (1916).
- (151) Feist, Awe, Kuklinski, and Volksen, *Arch. Pharm.*, 276, 271-9 (1938); *Chem. Abstr.*, 32, 6651 (1938).
- (152) Feist, Awe, and Kuklinski, *Arch. Pharm.*, 276, 420-31 (1938); *Chem. Abstr.*, 33, 1327 (1939).
- (153) Whitmore, Herr, Clarke, Rowland, and Schiessler, *J. Am. Chem. Soc.*, 67, 2059-61 (1945).
- (154) Jaeger and Robinson, *J. Chem. Soc.*, 1941, 744-7.
- (155) Garner and Hellerman, *J. Am. Chem. Soc.*, 68, 823-5 (1946).
- (156) Campbell and Easton, *J. Chem. Soc.*, 1949, 340-5.
- (157) Butenandt, Mamoli, and Heusner, *Ber.*, 72B, 1614-7 (1939).
- (158) Walton, Ofner, and Thorpe, *J. Chem. Soc.*, 1949, 648-55.
- (159) Tolbert, Christenson, Chang, and Sah, *J. Org. Chem.*, 14, 525-9 (1949).
- (160) Dupré, Elks, Hems, Speyer, and Evans, *J. Chem. Soc.*, 1949, 500-10.
- (161) Attenburrow, Elks, Hems, and Speyer, *J. Chem. Soc.*, 1949, 510-8.
- (162) Bergmann, *J. Org. Chem.*, 4, 1-13 (1939).
- (163) Whitmore, Schiessler, Rowland, and Cosby, *J. Am. Chem. Soc.*, 69, 235-7 (1947).
- (164) Dutta, *Science and Culture*, 7, 316-7 (1941); *Chem. Abstr.*, 36, 3156 (1942).
- (165) Callen, Dornfeld, and Coleman, *Organic Syntheses*, 28, 6-8 (1948).
- (166) Richtzenhain, *Ber.*, 77B, 1-6 (1944).
- (167) Bachmann and Kloetzel, *J. Org. Chem.*, 3, 55-61 (1938).
- (168) Berge, Wittfeld, and Wildt, *Ber.*, 67B, 238-44 (1934).
- (169) Thorpe, Walton, and Ofner, *Nature*, 160, 605-6 (1947).
- (170) Easton, Gardner, Evanick, and Stevens, *J. Am. Chem. Soc.*, 70, 76-8 (1948).
- (171) Schultz, Robb, and Sprague, *J. Am. Chem. Soc.*, 69, 188-9 (1947).
- (172) Schultz, Robb, and Sprague, *J. Am. Chem. Soc.*, 69, 2454-9 (1947).
- (173) Velluz and Muller, *Compt. rend.*, 226, 411 (1948); *Chem. Abstr.*, 42, 4596 (1948).
- (174) Schönberg, *Ber.*, 58B, 580-6 (1925).

- (175) Anderson and Thomas, *J. Am. Chem. Soc.*, 65, 234-8 (1943).
(176) Buu-Hoï, Nguyen-Hoàn, Lecocq, and de Clercq, *Rec. trav. chim.*, 67, 795-812 (1948).
(177) Biltz, *Ber.*, 60B, 2413 (1927).
(178) Nekrassov, *Ber.*, 60B, 1756-8 (1927).
(179) Meyer, *J. prakt. Chem.*, [2], 82, 521-38 (1910).
(180) Grignard, *Compt. rend.*, 152, 388-90 (1911); *Chem. Abstr.*, 5, 1589 (1911).
(181) Grignard and Courtot, *Bull. soc. chim.*, [4], 17, 228-31 (1915).
(182) Grignard, Bellet, and Courtot, *Ann. chim.*, [9], 4, 28-57 (1915).
(183) Grignard and Perrichon, *Ann. chim.*, [10], 5, 5-36 (1925).
(184) Grignard and Courtot, *Compt. rend.*, 158, 1763-6 (1914); *Chem. Abstr.*, 8, 3436 (1914).
(185) Willemart, *Ann. chim.*, [10], 12, 345-423 (1929).
(186) Grignard and Kasichi Ono, *Bull. soc. chim.*, [4], 39, 1589-94 (1926).
(187) Grignard, Bellet, and Courtot, *Ann. chim.*, [9], 12, 364-93 (1919).
(188) Coleman and Leeper, *Proc. Iowa Acad. Sci.*, 47, 201-5 (1940); *Chem. Abstr.*, 35, 7374 (1941).
(189) Ostrogovich, *Chem.-Ztg.*, 36, 738-9 (1912); *Chem. Abstr.*, 6, 2911 (1912).
(190) Majima, Shigematsu, and Rokkaku, *Ber.*, 59B, 1453-6 (1924).
(191) Grignard and Bellet, *Compt. rend.*, 155, 44-6 (1912); *Chem. Abstr.*, 6, 2739 (1912).
(192) Jones, *J. Am. Chem. Soc.*, 70, 143-4 (1948).
(193) Fuson, Emmons, and Tull, *J. Org. Chem.*, 16, 648-51 (1951).
(194) Akabori and Saito, *Ber.*, 63B, 2245-8 (1930).
(195) Kroeger and Nieuwland, *J. Am. Chem. Soc.*, 58, 1861-3 (1936).
(196) Darmon, *Compt. rend.*, 197, 1328-9 (1933).
(197) Maruyama, *Sci. Papers Inst. Phys. Chem. Research* (Tokyo), 20, 53-62 (1933); *Chem. Abstr.*, 27, 1863 (1933).
(198) Baddeley, *J. Chem. Soc.*, 1944, 232-6.
(199) Erlenmeyer and Marbet, *Helv. Chim. Acta*, 29, 1946-9 (1946).
(200) Woodward and Eastman, *J. Am. Chem. Soc.*, 68, 2229-35 (1946).
(201) Niemann, Benson, and Mead, *J. Org. Chem.*, 8, 397-404 (1943).
(202) Khaletskii, *J. Gen. Chem. (U.S.S.R.)*, 15, 524-9 (1945); *Chem. Abstr.*, 40, 4696 (1946).
(203) Quillico, Fusco, and Rosnati, *Gazz. chim. ital.*, 76, 87-107 (1946); *Chem. Abstr.*, 41, 383 (1947).
(204) Compère, *Bull. soc. chim. Belg.*, 44, 523-6 (1935).
(205) Lutz, Allison, Asburn, Bailey, Clark, Codington, Deinert, Freek, Jordan, Leake, Martin, Nicodemus, Rowlett, Shearer, Smith, and Wilson, *J. Org. Chem.*, 12, 617-703 (1947).
(206) Willemart, *Bull. soc. chim.*, [5], 2, 867-82 (1935).
(207) Tsatsas, *Ann. chim.*, [12], 1, 342-94 (1946).
(208) Miescher and Marxer, U. S. Patent 2,411,664, Nov. 26, 1946; *Chem. Abstr.*, 41, P6276 (1947).
(209) Bachmann and Brockway, *J. Org. Chem.*, 13, 384-9 (1948).
(210) Hems and Elks, British Patent 627,280, Aug. 4, 1949; *Chem. Abstr.*, 44, P3535 (1950).
(211) Mousseron and Jacquier, *Compt. rend.*, 226, 256-8 (1948); *Chem. Abstr.*, 42, 3734 (1948).
(212) Fuson, Gaertner, and Chadwick, *J. Org. Chem.*, 13, 489-95 (1948).
(213) Bachmann, *J. Org. Chem.*, 1, 347-53 (1936).
(214) Hartung, Munch, and Crossley, *J. Am. Chem. Soc.*, 57, 1091-3 (1935).
(215) Davies, Kefford, and Osborne, *J. Chem. Soc.*, 1939, 360-1.
(216) Piper and Wright, *J. Am. Chem. Soc.*, 72, 1669-74 (1950).

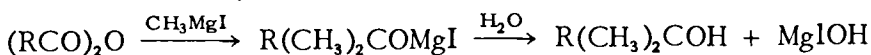
- (217) Birch, Dean, Fidler, and Lowry, *J. Am. Chem. Soc.*, 71, 1362-9 (1949).
- (218) Richtzenhain and Nippus, *Ber.*, 77B, 566-72 (1944).
- (219) Baker and Smith, *J. Chem. Soc.*, 1936, 346-8.
- (220) Maxim and Georgescu, *Bull. soc. chim.*, [5], 3, 1114-24 (1936).
- (221) Fieser and Seligman, *J. Am. Chem. Soc.*, 58, 2482-7 (1936).
- (222) Nunn and Henze, *J. Org. Chem.*, 12, 540-2 (1947).
- (223) Kloetzel and Wildman, *J. Org. Chem.*, 11, 390-4 (1946).
- (224) Birch and Robinson, *J. Chem. Soc.*, 1943, 501-2.
- (225) Campbell, Kirwin, LaForge, and Campbell, *J. Am. Chem. Soc.*, 68, 1844-6 (1946).
- (226) Fieser and Riegel, *J. Am. Chem. Soc.*, 59, 2561-5 (1937).
- (227) Maxim and Aldea, *Bull. soc. chim.*, [5], 3, 1329-34 (1936).
- (228) Schiessler, Rytina, and Whitmore, *J. Am. Chem. Soc.*, 70, 529-30 (1948).
- (229) Kuwada and Sasagawa, *Bull. Chem. Soc. Japan*, 16, 423-7 (1941); *Chem. Abstr.*, 41, 4472 (1947).
- (230) Birch and Robinson, *J. Chem. Soc.*, 1942, 488-97.
- (231) Fuson and Chadwick, *J. Org. Chem.*, 13, 484-8 (1948).
- (232) Elderfield, Pitt, and Wempen, *J. Am. Chem. Soc.*, 72, 1334-45 (1950).
- (233) Lutz and Smith, *J. Am. Chem. Soc.*, 63, 1148-50 (1941).
- (234) Gaylord and Becker, *J. Org. Chem.*, 15, 305-16 (1950).
- (235) Frank and Weatherbee, *J. Am. Chem. Soc.*, 70, 3482-3 (1948).
- (236) Johnson, Jacobs, and Schwartz, *J. Am. Chem. Soc.*, 60, 1885-9 (1938).
- (237) Moffett and Shriner, *Organic Syntheses*, 21, 79-80 (1941).
- (238) Tilford, Shelton, and Van Campen, *J. Am. Chem. Soc.*, 70, 4001-8 (1948).
- (239) Blicke and Powers, *J. Am. Chem. Soc.*, 51, 3378-83 (1929).

CHAPTER XI

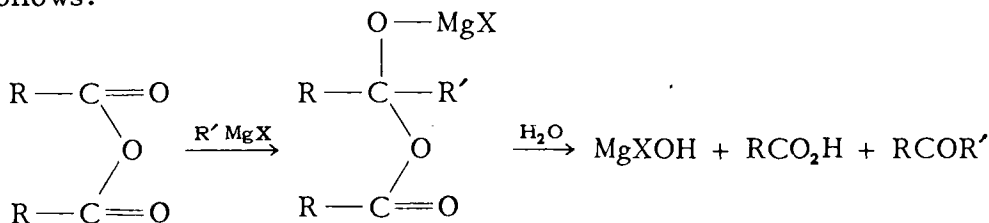
Reactions of Grignard Reagents with Carboxylic Anhydrides

THE "NORMAL" REACTIONS

Tissier and Grignard¹ found that the addition of ethereal solutions of acetic or benzoic anhydride to ethereal methylmagnesium iodide led to the formation of tertiary alcohols.



By employing high dilution and reverse addition, and operating at low temperature (-23°), Fournier² was able to show that the first step in the reaction is ketone (and acid) formation. He formulated the reaction as follows:



Because of the availability of competitive methods at least as satisfactory, and often more so, the reactions of acyclic carboxylic anhydrides with Grignard reagents have found little use in the preparation of ketones, although Newman³ has had good success in the preparation of methyl ketones by operating with Dry-Ice cooling in the neighborhood of -70° , as have Brokaw and Brode.⁴ Newman attributes the success of his method to increased stability and decreased solubility of the initial reaction product at low temperatures.

This method has been further studied by Newman and Smith,⁵ who report that the yield of 2-hexanone from acetic anhydride and *n*-butylmagnesium bromide varies but little from 34° to -37° (48-51%), but gradually improves thereafter as the temperature is lowered to -82° (83%). The temperature effect was found to be about the same for the reactions of *t*-butylmagnesium chloride with acetic anhydride and phenylmagnesium

¹ Tissier and Grignard, *Compt. rend.*, 132, 683-5 (1901); *Chem. Zentr.*, 1901, 1, 930.

² Fournier, *Bull. soc. chim.*, [3], 31, 483 (1904); [3], 35, 14 (1906); [4], 7, 836-40 (1910).

³ Newman and Booth, *J. Am. Chem. Soc.*, 67, 154 (1945); Newman and O'Leary, *ibid.*, 68, 258-61 (1946).

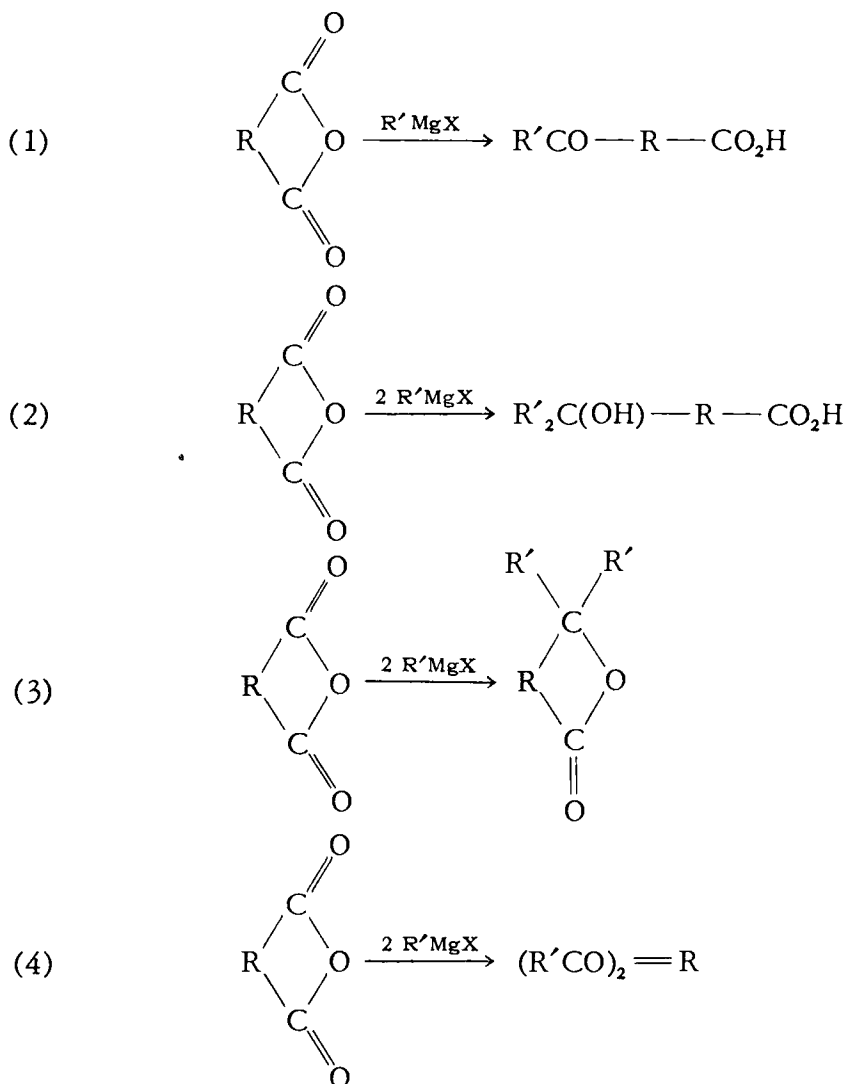
⁴ Brokaw and Brode, *J. Org. Chem.*, 13, 194-9 (1948).

⁵ Newman and Smith, *J. Org. Chem.*, 13, 592-8 (1948).

bromide with benzoic anhydride. The reactions of various Grignard reagent-anhydride pairs at -70° were studied, and the method appears to have general applicability.

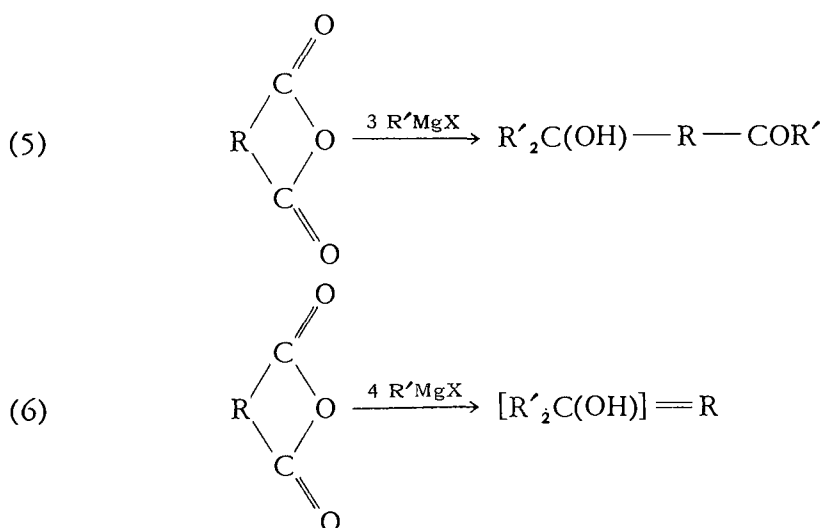
The use of organocadmium (or -zinc) compounds prepared from Grignard reagents, which has proved so successful in the preparation of ketones from carbonyl chlorides (*q.v.*), has been explored somewhat. According to Cason,⁶ however, the symmetrical acyclic anhydrides give yields inferior to those obtainable with the corresponding acid chlorides. For the preparation of keto acids the half-ester chlorides are recommended as superior to the corresponding cyclic anhydrides, except in the case of the phthalic acid derivatives whose half-ester chlorides are unstable.⁷ Examples of such preparations are, however, included in Table XI-I.

All the theoretically possible "normal" reactions of Grignard reagents with cyclic anhydrides have been observed (though not with any single anhydride), and examples are recorded in Table XI-I.



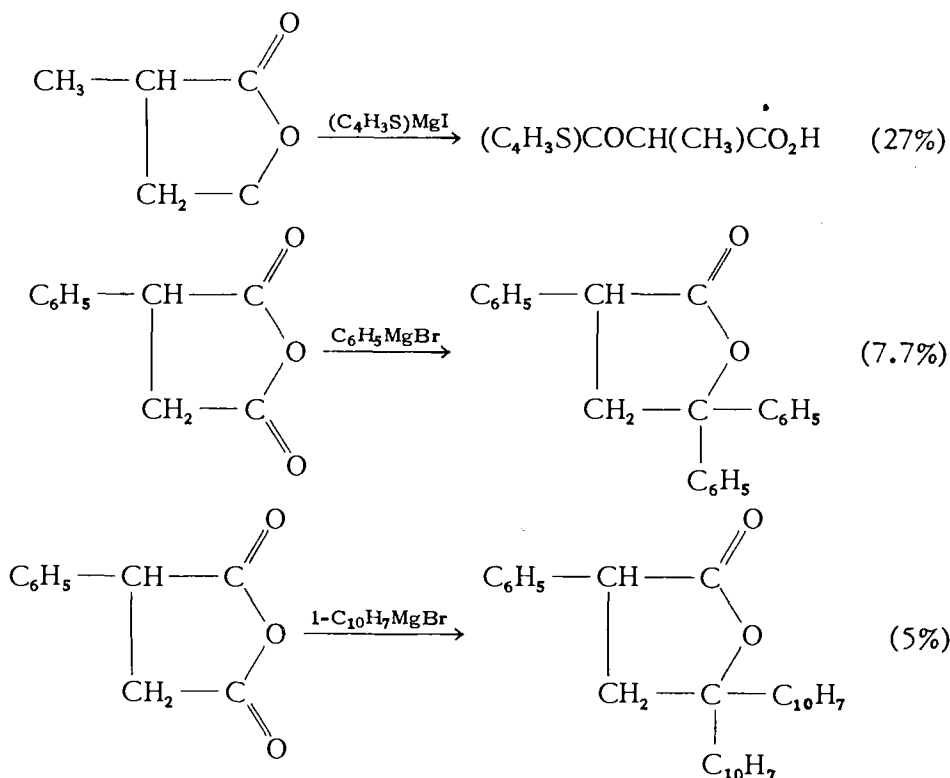
⁶Cason, *Chem. Revs.*, 40, 15-32 (1947).

⁷Zelinsky, *Ber.*, 30, 1010-3 (1887).



On the basis of the available data, reaction 3 appears to be by far the most common of those consuming two molecules of Grignard reagent, with reaction 2 in the runner-up position, and reaction 4 extremely rare. It is highly probable that reaction products 5 and 6 result in most cases from further reaction of the product of reaction 3.

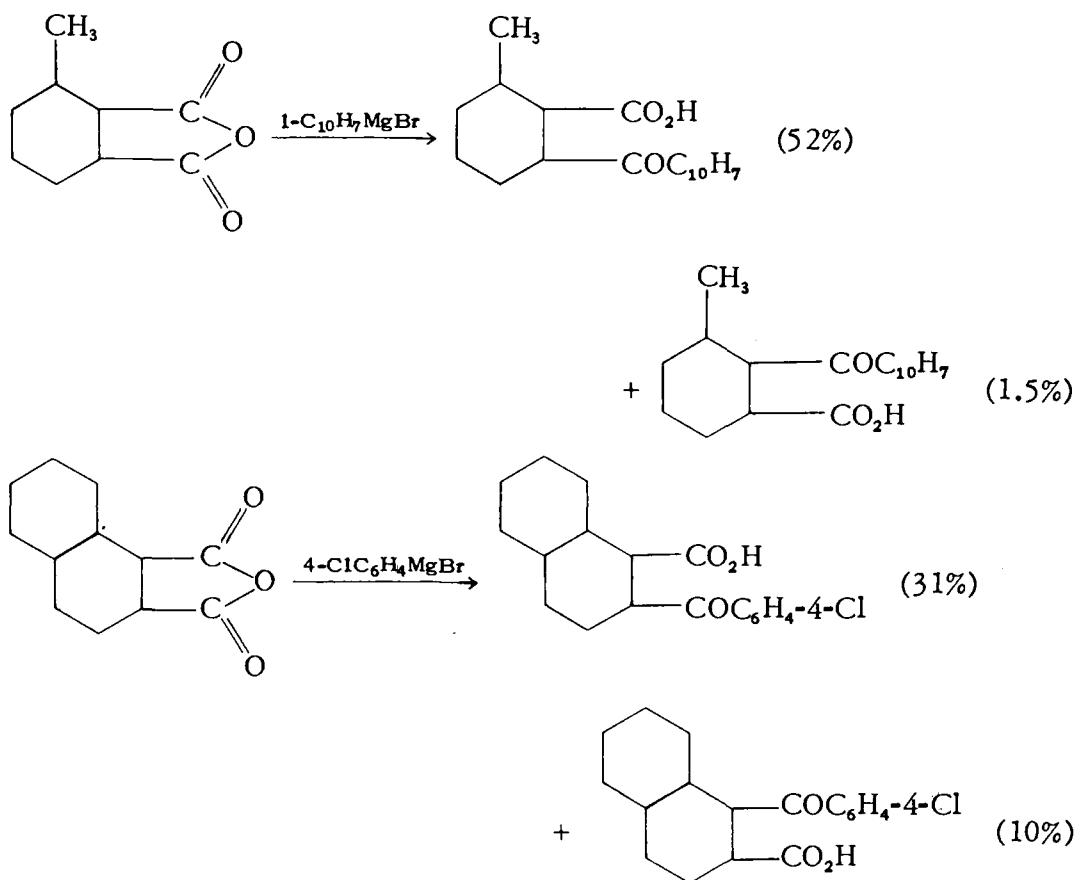
If the reactions of thienylmagnesium iodide with methylsuccinic anhydride⁸ and of phenyl- and α -naphthylmagnesium bromides with phenylsuccinic anhydride⁹ may be regarded as typical (although the yields reported are low), an *alpha* substituent tends to inhibit reaction at the adjacent carbonyl group.



⁸ Kitchin and Sandin, *J. Am. Chem. Soc.*, 67, 1645-6 (1945).

⁹ Weizmann, Blum-Bergmann, and Bergmann, *J. Chem. Soc.*, 1935, 1370-1.

Newman¹⁰ has made a similar observation as regards the 3-substituted phthalic anhydrides.



SPECULATIONS CONCERNING REACTION MECHANISMS

Newman interprets these findings as indicating that the "normal" reaction of a Grignard reagent with a carboxylic anhydride takes place, predominantly at least, by addition at a carbonyl group. To account for what he regards as the improbable ratio of isomeric reaction products in such cases, and for the reactivity of the 3,6- and 3,4,6-substituted phthalic anhydrides, Newman postulates a "metathetical"* reaction mechanism which becomes competitive with the "normal" addition reaction. This may be the correct interpretation. However, if the actual reaction mechanism is bimolecular, and resembles that of the nitriles (*q.v.*), steric hindrance, while probably appreciable, would be much less pronounced

¹⁰(a) Fieser and Newman, *J. Am. Chem. Soc.*, 68, 2376-82 (1936); (b) Newman, *ibid.*, 59, 1003-6 (1937); (c) Newman and Orchin, *ibid.*, 60, 586-9 (1938); (d) Newman, *ibid.*, 60, 1368-70 (1938); (e) Newman and Orchin, *ibid.*, 61, 244-7 (1939); (f) Newman and McCleary, *ibid.*, 63, 1542-4 (1941); (g) Newman and Wise, *ibid.*, 63, 2109-13 (1941); (h) Newman and Lord, *ibid.*, 66, 733-5 (1944). See also: (i) Nichol and Sandin, *ibid.*, 69, 2256-8 (1947).

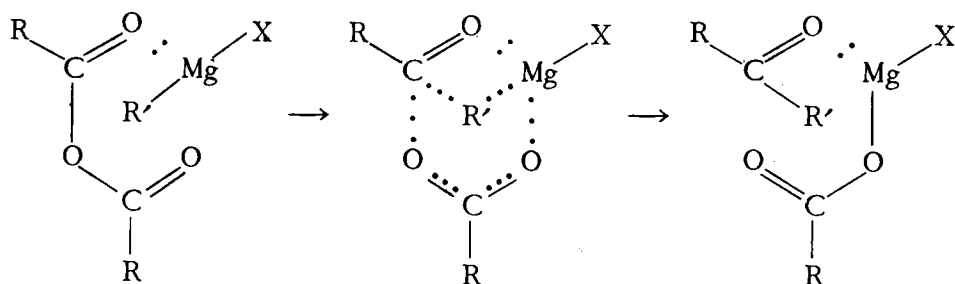
*Actually, the term metathetical is primarily stoichiometric in significance. It can be regarded as having mechanistic connotations only in so far as it eliminates certain types of reaction mechanism from consideration.

than in a trimolecular mechanism like that postulated for the ketones (*q.v.*), and, by inference, for the aldehydes, and at least some of the esters. In that case the assumption of two competitive reaction mechanisms for the partially hindered anhydrides appears unnecessary.

Actually, nothing is certainly known concerning the mechanism of the reaction. In general, anhydrides react with Grignard reagents too rapidly to permit of kinetic studies of the conventional sort. Matters are further complicated by the reactivity toward Grignard reagents of the initial product (or products), and by the tendency of the reaction systems to become heterogeneous, especially at low temperatures. Hence, even the order of these reactions is unknown. It is possible that some useful inferences might be drawn from competitive reaction studies, as they have been in the cases of the nitriles (*q.v.*) and the carbonyl halides (*q.v.*). At present, only speculation on the basis of analogy is possible.

It seems highly probable, however, that the necessary prelude to reaction is the formation of a Werner complex of some sort. This step is probably extremely rapid and is not rate-determining. In view of the ease and rapidity with which carbonyl complexes are formed in the presence of relatively large quantities of ether it seems likely that complex formation takes place at one of the carbonyl oxygen atoms rather than at the singly-bonded oxygen atom, which is more or less ethereal in character.

The conditions under which such reactions are often conducted (*i.e.*, by the slow addition of Grignard reagent solution to an excess of anhydride solution) would appear to argue (though not altogether conclusively) against the probability of a trimolecular mechanism for the first stage of reaction. Rearrangement of the Werner complex might lead to the formation of a relatively unstable intermediate compound by addition at the carbonyl double bond, as suggested by Fournier (*loc. cit.*²). If so, it seems probable that the intermediate might take the form of a new Werner complex involving a molecule of ketone and a molecule of magnesium salt.



The results of the low-temperature (-70°) studies of Newman and Smith (*loc. cit.*⁵) are consistent with a concept of this general nature. Treatment of the precipitated acetic anhydride-*n*-butylmagnesium bromide product with excess ethanol at -70° (and subsequent aqueous hydrolysis) liberates the ketone rather than butane, indicating that the product is not a simple Grignard reagent-anhydride Werner complex. At -70° the ethereal solution is ketone-free; allowed to warm to room temperature in the

presence of the precipitated product, it contains all the ketone present; recooled to -70° in the presence of the residual bromomagnesium acetate, it retains the ketone.

PREPARATIVE PROCEDURES

Newman's¹¹ method for the preparation of methyl ketones is described as follows:

"In a typical experiment, 0.2 mole of a titrated Grignard reagent was added slowly during one hour to a stirred solution of 40 g. of acetic anhydride in 100 ml. of dry ether in a 500-ml. 3-necked flask cooled by a mixture of Dry Ice and acetone in a Dewar flask. The added reagent was cooled by dripping through a tube externally cooled with Dry Ice. After stirring for two to three hours the cooling bath was removed and the mixture was treated with ammonium chloride solution. After washing out the acetic anhydride and acid with alkali the ether was fractionated and the ketones distilled.... The following Grignard reagents gave the corresponding methyl ketones in the following yields: *n*-butylmagnesium chloride, 79 percent; *n*-butylmagnesium bromide, 79 percent; *s*-butylmagnesium bromide, 78 percent; *t*-butylmagnesium chloride, 77 percent; phenylmagnesium bromide, 70 percent; benzylmagnesium chloride, 52 percent; and allylmagnesium bromide, 42 percent. With phenylmagnesium bromide and propionic anhydride a 59 percent yield of propiophenone was obtained."

The method of Bauer¹² for the preparation of 3,3-disubstituted phthalides may be summarized as follows: To a cooled ethereal solution of two molecular equivalents of Grignard reagent one molecular equivalent of finely powdered phthalic anhydride is added slowly. After completion of the addition the reaction mixture is allowed to stand for about an hour, and is then treated with water and dilute sulfuric acid, and extracted with ether. The ether is removed by distillation, and the oily residue is washed with dilute sodium carbonate solution, whereupon it solidifies. The yields claimed for the following Grignard reagents are as indicated: methyl- and ethylmagnesium iodides, 75-80 percent; phenylmagnesium bromide 70-75 percent; benzylmagnesium chloride, 60 percent.

Treating phthalic, 4-methoxyphthalic, tetrachlorophthalic, and 2,3-naphthalenedicarboxylic anhydrides with aryl Grignard reagents, Weizmann *et al.*¹³ have prepared some sixteen keto acids in 70-80 percent yields. Typical procedure is described essentially as follows. The anhydride is dissolved or suspended in boiling benzene or warm *n*-butyl ether on a water-bath, and 1.1 equivalent of Grignard solution is added slowly from a dropping funnel. The mixture is boiled for two hours, and is then treated with ice and sulfuric acid. The non-aqueous layer is extracted with sodium carbonate solution, and the alkaline extract is acidified, the keto acid being thus obtained.

¹¹ Newman and Booth, *J. Am. Chem. Soc.*, 67, 154 (1945).

¹² Bauer, *Ber.*, 37, 735-7 (1904); 38, 240-1 (1905).

¹³ Weizmann, Bergmann, and Bergmann, *J. Chem. Soc.*, 1935, 1367-70.

TABLE XI-I
REACTIONS OF GRIGNARD REAGENTS WITH CARBOXYLIC ANHYDRIDES

<u>Anhydride</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄O₃Br₂			
Dibromomaleic anhydride (20.0 g.)	CH ₃ Mgl (33.4 g. CH ₃ I)	3,3-Dimethyl-4,5-dibromo-2-oxa-4-cyclopenten-1-one (7-8 g., 33-38%)	1
C₄H₂O₃			
Maleic anhydride	C ₂ H ₅ MgBr	(C ₂ H ₅) ₂ C(OH)CH=CHCO ₂ H; CH ₃ CH=C(C ₂ H ₅)CH=CHCO ₂ H (?); C ₂ H ₅ COCH ₂ CH(C ₂ H ₅)C(C ₂ H ₅) ₂ OH	2
Maleic anhydride	<i>n</i> -C ₄ H ₉ MgBr	(<i>n</i> -C ₄ H ₉) ₂ C(OH)CH=CHCO ₂ H	2
Maleic anhydride (1.0 mole)	C ₆ H ₅ MgBr (4.5 moles C ₆ H ₅ Br)	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)COC ₆ H ₅ (ca. 10 g.); oil (ca. 10 g.)	3
Maleic anhydride (8.8 g.)	C ₆ H ₅ MgBr (15.7 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)COC ₆ H ₅ ; C ₆ H ₅ COCH ₂ CH(C ₆ H ₅)CO ₂ H	27
Maleic anhydride	C ₆ H ₅ CH ₂ MgCl	(C ₆ H ₅ CH ₂) ₂ C(OH)CH=CHCO ₂ H; [C ₆ H ₅ CH=C(CH ₂ C ₆ H ₅)CH=] ₂	2
C₄H₄O₃			
Succinic anhydride (10.0 g.)	C ₂ H ₅ MgBr (69.6 g. C ₂ H ₅ Br)	2,2,5,5-Tetraethyltetrahydrofuran (?)	9
Succinic anhydride (22.5 g.)	<i>i</i> -C ₅ H ₁₁ MgBr (0.3 mole C ₅ H ₁₁ Br) + CdCl ₂	<i>i</i> -C ₅ H ₁₁ COCH ₂ CH ₂ CO ₂ H (11.9 g., 30.8%)	7,6
Succinic anhydride (0.5 equiv.)	<i>i</i> -C ₅ H ₁₁ MgBr + ZnCl ₂	<i>i</i> -C ₅ H ₁₁ COCH ₂ CH ₂ CO ₂ H (5-10%)	6
Succinic anhydride (10.0 g.)	C ₆ H ₅ MgBr (17.3 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH ₂ CH ₂ CO ₂ H	8
Succinic anhydride (10 g.)	C ₆ H ₅ MgBr (100 g. C ₆ H ₅ Br)	[(C ₆ H ₅) ₂ C(OH)CH ₂ -] ₂ (10 g., 26%)	9
Succinic anhydride	C ₆ H ₅ MgBr (0.5 equiv.)	C ₆ H ₅ COCH ₂ CH ₂ CO ₂ H (50-70%)*	10
Succinic anhydride (0.16 mole)	C ₆ H ₅ MgBr (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	C ₆ H ₅ COCH ₂ CH ₂ CO ₂ H	11

* Reaction at -70°.

TABLE XI-I (Continued)

Anhydride	RMgX	Product(s)	Ref.
C₄H₄O₃ (cont.)			
Succinic anhydride (10.0 g.)	C ₆ H ₅ CH ₂ MgCl (75.6 g. C ₇ H ₇ Cl)	[(C ₆ H ₅ CH ₂) ₂ C(OH)CH ₂ —] ₂ (12.0 g., 27%)	9
Succinic anhydride	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ COCH ₂ CH ₂ CO ₂ H (54.4%)	12
Succinic anhydride	C ₆ H ₅ CH(CO ₂ Na)MgCl*	C ₆ H ₅ CH ₂ COCH ₂ CH ₂ CO ₂ H (64.5%)	12
Succinic anhydride (10.0 g.)	1-C ₁₀ H ₇ MgBr (22.8 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ COCH ₂ CH ₂ CO ₂ H (2.5 g.)	13
Succinic anhydride (10.0 g.)	2-C ₁₀ H ₇ MgBr (22.8 g. C ₁₀ H ₇ Br)	2-C ₁₀ H ₇ COCH ₂ CH ₂ CO ₂ H (4.0 g.)	13
C₄H₄O₃Cl₂			
(ClCH ₂ CO) ₂ O	<i>n</i> -C ₄ H ₉ MgBr (0.5 equiv.)	<i>n</i> -C ₄ H ₉ COCH ₂ Cl (35–50%) [†]	10
(ClCH ₂ CO) ₂ O (0.6 mole)	C ₆ H ₅ CH ₂ MgCl (0.5 mole)	ClCH ₂ COC ₆ H ₄ -2-CH ₃ (42%, crude)	14
C₄H₆O₃			
(CH ₃ CO) ₂ O	CH ₃ MgI	<i>t</i> -C ₄ H ₉ OH	15
(CH ₃ CO) ₂ O	C ₂ H ₅ MgBr	CH ₃ COC ₂ H ₅ ("very little"); CH ₃ (C ₂ H ₅) ₂ COH	16
(CH ₃ CO) ₂ O	Pyrazolyl-MgBr	No reaction	17
(CH ₃ CO) ₂ O (40 g.)	H ₂ C=CHCH ₂ MgBr (0.2 mole)	CH ₃ COCH ₂ CH=CH ₂ (42%) [†]	18
(CH ₃ CO) ₂ O	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ CO- <i>i</i> -C ₃ H ₇ (45%)	19
(CH ₃ CO) ₂ O	<i>i</i> -C ₃ H ₇ MgBr (0.5 equiv.)	CH ₃ CO- <i>i</i> -C ₃ H ₇ (74–78%) [†]	10
(CH ₃ CO) ₂ O	H ₂ C=CHC≡CMgBr	Product(s) explosive	20
(CH ₃ CO) ₂ O (40 g.)	<i>n</i> -C ₄ H ₉ MgX [‡] (0.2 mole)	CH ₃ CO- <i>n</i> -C ₄ H ₉ (79%) [†]	18
(CH ₃ CO) ₂ O (55 g., 0.54 mole)	<i>n</i> -C ₄ H ₉ MgBr (0.257 mole)	CH ₃ CO- <i>n</i> -C ₄ H ₉ (48–83%) [§]	10

* In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135–54 (1931), this "Grignard reagent" should be formulated as an enolate.

[†] Reaction at –70°.

[‡] X = Cl, Br.

[§] Reactions at temperatures ranging from 34 to –82°; the following yields are reported for the temperatures indicated: 34°, 48%; 5°, 48%; –26°, 50%; –37°, 51%; –46°, 68%; –54°, 64%; –67°, 79%; –82°, 83%.

TABLE XI-I (Continued)

Anhydride	RMgX	Product(s)	Ref.
C₄H₆O₃ (cont.)			
(CH ₃ CO) ₂ O (0.16 mole)	<i>n</i> -C ₄ H ₉ MgBr (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	CH ₃ CO- <i>n</i> -C ₄ H ₉ (56%)	11
(CH ₃ CO) ₂ O	<i>i</i> -C ₄ H ₉ MgCl (1 equiv.)	CH ₃ CO- <i>i</i> -C ₄ H ₉ ("very little")	42, 16
(CH ₃ CO) ₂ O (40 g.)	<i>s</i> -C ₄ H ₉ MgBr (0.2 mole)	CH ₃ CO- <i>s</i> -C ₄ H ₉ (78%)*	18
(CH ₃ CO) ₂ O (40 g.)	<i>t</i> -C ₄ H ₉ MgCl (0.2 mole)	CH ₃ CO- <i>t</i> -C ₄ H ₉ (77%)*	18
(CH ₃ CO) ₂ O (1 mole)	2-Thenyl-MgCl (0.190 mole)	2-Methyl-3-acetylthiophene (6.52 g., 25%); 1,3-bis-(2-thienyl)-propene (?) (9.08 g., 31%)	76
(CH ₃ CO) ₂ O	<i>i</i> -C ₅ H ₁₁ MgX [†] (1 equiv.)	CH ₃ CO- <i>i</i> -C ₅ H ₁₁ ; CH ₃ CO ₂ - <i>i</i> -C ₅ H ₁₁	16, 42
(CH ₃ CO) ₂ O	D- <i>s</i> -C ₄ H ₉ CH ₂ MgBr [‡]	D(+)-CH ₃ COCH ₂ CH(CH ₃)C ₂ H ₅ ("excellent yield")*	22
(CH ₃ CO) ₂ O	C ₆ H ₅ MgBr (0.5 equiv.)	CH ₃ COC ₆ H ₅ (73-75%)*	10, 18
(CH ₃ CO) ₂ O (0.16 mole)	C ₆ H ₅ MgBr (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	CH ₃ COC ₆ H ₅ (75%)	11
(CH ₃ CO) ₂ O (0.5 mole)	<i>n</i> -C ₄ H ₉ C≡CMgCl (0.25 mole)	CH ₃ COC≡C- <i>n</i> -C ₄ H ₉ (18 g.); <i>n</i> -C ₄ H ₉ C≡CH (8 g.) [§]	23
(CH ₃ CO) ₂ O (1.0 mole)	<i>n</i> -C ₄ H ₉ C≡CMgBr (0.5 mole)	CH ₃ COC≡C- <i>n</i> -C ₄ H ₉ (20 g.); CH ₃ (<i>n</i> -C ₄ H ₉ C≡C) ₂ COH (8 g.) [¶]	23
CH ₃ CO ₂ O (0.5 mole)	<i>n</i> -C ₄ H ₉ C≡CMgX [‡] (0.25 mole)	CH ₃ COC≡C- <i>n</i> -C ₄ H ₉ (10-20%) [§]	23
(CH ₃ CO) ₂ O	(CH ₂) ₅ CHMgBr	CH ₃ COCH(CH ₂) ₅ (56%)	19
(CH ₃ CO) ₂ O (25 g.)	2,6-Cl ₂ C ₆ H ₃ CH ₂ MgCl (0.056 mole)	CH ₃ COCH ₂ C ₆ H ₃ -2,6-Cl ₂	14

* Reaction at -70°.

[†]X = Cl, Br.[‡]From D(+)-CH₃(C₂H₅)CHCH₂Br.[§]Slow (two and one-half hours) addition of anhydride to stirred Grignard reagent suspension at -30 to -25°; two hours stirring at -30°; 2 hrs. stirring at -5°.[¶]Slow (three hours) addition of Grignard reagent solution to stirred, ice-salt-cooled anhydride; two hours stirring.[‡]X = Br, I.

TABLE XI-I (Continued)

Anhydride	RMgX	Product(s)	Ref.
C₄H₆O₃ (cont.)			
(CH ₃ CO) ₂ O (0.53 mole)	2-ClC ₆ H ₄ CH ₂ MgCl (0.07 mole)	CH ₃ COC ₆ H ₃ -2-CH ₃ -3-Cl	14
(CH ₃ CO) ₂ O (1.65 mole)	C ₆ H ₅ CH ₂ MgCl (0.55 mole)	CH ₃ COC ₆ H ₄ -2-CH ₃ (30%)*	14
(CH ₃ CO) ₂ O (40 g.)	C ₆ H ₅ CH ₂ MgCl (0.2 mole)	CH ₃ COCH ₂ C ₆ H ₅ † (52%)	18
(CH ₃ CO) ₂ O (0.5 mole)	<i>n</i> -C ₅ H ₁₁ C≡CMgCl (0.25 mole)	CH ₃ COC≡C- <i>n</i> -C ₅ H ₁₁ (22 g.); <i>n</i> -C ₅ H ₁₁ C≡CH (10 g.) †	23
(CH ₃ CO) ₂ O (0.5 mole)	<i>n</i> -C ₅ H ₁₁ C≡CMgX § (0.25 mole)	CH ₃ COC≡C- <i>n</i> -C ₅ H ₁₁ (10-20%) †	23
(CH ₃ CO) ₂ O (0.5 mole)	C ₆ H ₅ C≡CMgCl (0.25 mole)	CH ₃ COC≡CC ₆ H ₅ (40-45%); CH ₃ (C ₆ H ₅ C≡C) ₂ COH †	23
(CH ₃ CO) ₂ O (0.5 mole)	C ₆ H ₅ C≡CMgBr (0.25 mole)	CH ₃ COC≡CC ₆ H ₅ (3 g.); CH ₃ (C ₆ H ₅ C≡C) ₂ COH (30 g., crude) †	23
(CH ₃ CO) ₂ O (102 g.)	1-Cyclohexenylethynyl-MgBr (62 g. C ₆ H ₁₀)	1-Acetoethynylcyclohexene (36 g.)	72,71,73
(CH ₃ CO) ₂ O (150.0 g.)	β-(1-Tetralyl)ethyl-MgCl (141.4 g. C ₁₂ H ₁₅ Cl)	4-(1-Tetralyl)-2-butanone 61% †	25
C₅H₆O₃			
Glutaric anhydride (11.4 g.)	CH ₃ MgI (15.6 g. CH ₃ I)	CH ₃ CO(CH ₂) ₃ CO ₂ H; lactone (trace); unsat'd acid (trace)**	8

* Other products not investigated probably include CH₃(C₆H₅CH₂)₂COH.

† Reaction at -70°.

‡ Slow (two and one-half hours) addition of anhydride to stirred Grignard reagent suspension at -30 to -25°; two hours stirring at -30°; 2 hrs. stirring at -5°.

§ X = Br, I.

¶ Slow (three hours) addition of Grignard reagent solution to stirred, ice-salt-cooled anhydride; two hours stirring.

‡ Reaction at -78°.

** Slow addition of Grignard reagent solution to ice-cooled C₆H₆-anhydride solution; twenty-four hours standing.

TABLE XI-I (Continued)

<u>Anhydride</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₆O₃ (cont.)			
Glutaric anhydride (10 g.)	CH ₃ MgI (28 g. CH ₃ I)	δ-Methyl-δ-caprolactone (1.5 g.); (CH ₃) ₂ C=CHCH ₂ CH ₂ CO ₂ H (2 g.)*	8
Glutaric anhydride	<i>n</i> -C ₄ H ₉ MgBr + CdCl ₂	<i>n</i> -C ₄ H ₉ CO(CH ₂) ₃ CO ₂ H (30.5%)	26
Methylsuccinic anhydride (14 g.)	2-Thienyl-MgI (25 g. CH ₃ I)	α-Methyl-β-(2-thenoyl)propionic acid (6.6 g., 27%)	24
C₆H₆O₃			
Dimethylmaleic anhydride (6.4 g.)	C ₆ H ₅ MgBr (17.3 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH(CH ₃)C(CH ₃)(C ₆ H ₅)CO ₂ H [2 forms: m. 183–185° (3.4 g.); m. 112–114° (8.1 g.)]	27,28
1,2-Cyclobutanedicarboxylic anhydride (3.2 g.)	C ₆ H ₅ MgBr (24 ml. 2.1 N)	4,4-Diphenyl-3-oxabicyclo[3.2.0]heptan- 2-one	29
1,2-Cyclobutanedicarboxylic anhydride (3.2 g., 0.025 mole)	C ₆ H ₅ MgBr (0.025 mole)	<i>trans</i> -2-Benzoylcyclobutanecarboxylic acid	29
C₆H₁₀O₃			
(C ₂ H ₅ CO) ₂ O	<i>n</i> -C ₄ H ₉ MgBr (0.5 equiv.)	C ₂ H ₅ CO- <i>n</i> -C ₄ H ₉ (74%) [†]	10
(C ₂ H ₅ CO) ₂ O	<i>i</i> -C ₄ H ₉ MgCl	C ₂ H ₅ CO- <i>i</i> -C ₄ H ₉ [†]	21,16
(C ₂ H ₅ CO) ₂ O	D- <i>s</i> -C ₄ H ₉ CH ₂ MgBr [§]	D(+)-C ₂ H ₅ COCH ₂ CH(CH ₃)C ₂ H ₅ ("excellent yield") [†]	22
(C ₂ H ₅ CO) ₂ O	C ₆ H ₅ MgBr	C ₂ H ₅ COC ₆ H ₅ (59%) [†]	18
(C ₂ H ₅ CO) ₂ O (0.16 mole)	C ₆ H ₅ MgBr (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	C ₂ H ₅ COC ₆ H ₅ (68%)	11

* Gradual addition of Grignard reagent solution to C₆H₆-anhydride solution; twenty-four hours standing; heating to b.p. of C₆H₆.

[†] Reaction at -70°.

[‡] Reaction at -20°.

[§] From D(+)-CH₃(C₂H₅)CHCH₂Br.

TABLE XI-I (Continued)

<u>Anhydride</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₃O₃N			
Cinchomeric anhydride	C ₂ H ₅ MgI	3-(γ -Hydroxy- γ -amyl)pyridine-4-carboxylic acid lactone; 4-(γ -hydroxy- γ -amyl)pyridine-3-carboxylic acid lactone ("small yields")	30
C₇H₄O₄S			
2-Sulfobenzoic anhydride	C ₆ H ₅ MgBr	2-HO(C ₆ H ₅) ₂ CC ₆ H ₄ SO ₃ H; 2- α -hydroxy-benzhydrylbenzenesulfonic acid lactone (<i>ca.</i> 10%)	31
C₇H₁₀O₃			
β , β -Dimethylglutaric anhydride (20.3 g.)	C ₂ H ₅ MgBr (24 g. C ₂ H ₅ Br)	C ₂ H ₅ COCH ₂ C(CH ₃) ₂ CH ₂ CO ₂ H (4.8 g.); β , β -dimethyl- δ -ethyl- δ -enanthylo lactone	8
C₈O₃Cl₄			
Tetrachlorophthalic anhydride	CH ₃ MgI (2 equiv.)	3,3-Dimethyl-4,5,6,7-tetrachlorophthalide	32
Tetrachlorophthalic anhydride	C ₂ H ₅ MgBr (2 equiv.)	3-Ethyl-4,5,6,7-tetrachlorophthalide	32
Tetrachlorophthalic anhydride	4-BrC ₆ H ₄ MgBr (10% excess)	3,3-Di-(<i>p</i> -bromophenyl)-4,5,6,7-tetrachlorophthalide	33
Tetrachlorophthalic anhydride	C ₆ H ₅ MgBr (10% excess)	2-C ₆ H ₅ CO-3,4,5,6-Cl ₄ C ₆ CO ₂ H (70-80%)	33
Tetrachlorophthalic anhydride	4-CH ₃ OC ₆ H ₄ MgBr	2-(<i>p</i> -CH ₃ OC ₆ H ₄ CO)-3,4,5,6-Cl ₄ C ₆ CO ₂ H (70-80%)	33
Tetrachlorophthalic anhydride	1-C ₁₀ H ₇ MgBr (10% excess)	2- α -C ₁₀ H ₇ CO-3,4,5,6-Cl ₄ C ₆ CO ₂ H (70-80%)	33
C₈H₄O₃			
Phthalic anhydride (0.16 mole)	CH ₃ MgBr (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	2-CH ₃ COC ₆ H ₄ CO ₂ H (62%)	11

TABLE XI-I (Continued)

<u>Anhydride</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₄O₃ (cont.)			
Phthalic anhydride	CH ₃ MgI (2 equiv.)	3,3-Dimethylphthalide	34,38
Phthalic anhydride	CH ₃ MgI (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	2-CH ₃ COC ₆ H ₄ CO ₂ H (47%)	11
Phthalic anhydride	C ₂ H ₅ MgBr (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	2-C ₂ H ₅ COC ₆ H ₄ CO ₂ H (67%)	11
Phthalic anhydride	C ₂ H ₅ MgI (2 equiv.)	3,3-Diethylphthalide	34,38
Phthalic anhydride	H ₂ C=CHCH ₂ Br + Mg	3,3-Diallylphthalide (70%)	35
Phthalic anhydride	<i>n</i> -C ₃ H ₇ MgBr (2 equiv.)	3,3-Di- <i>n</i> -propylphthalide	32
Phthalic anhydride	<i>i</i> -C ₃ H ₇ MgBr (2 equiv.)	3,3-Diisopropylphthalide	32
Phthalic anhydride	4-BrC ₆ H ₄ MgBr (10% excess)	2-(<i>p</i> -BrC ₆ H ₄ CO)C ₆ H ₄ CO ₂ H (70-80%)	33
Phthalic anhydride	C ₆ H ₅ MgBr	2-C ₆ H ₅ COC ₆ H ₄ CO ₂ H	47,36
Phthalic anhydride	C ₆ H ₅ MgBr (2 equiv.)	3,3-Diphenylphthalide (70-75%); 1,2-(C ₆ H ₅ CO) ₂ C ₆ H ₄	37
Phthalic anhydride (0.16 mole)	C ₆ H ₅ MgBr (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	2-C ₆ H ₅ COC ₆ H ₄ CO ₂ H (64%)	11
Phthalic anhydride	C ₆ H ₅ CH ₂ MgCl (2 equiv.)	3,3-Dibenzylphthalide (ca. 60%)	37
Phthalic anhydride (50 g.)	2-CH ₃ C ₆ H ₄ MgBr (205 ml., 1.125 M)	2-(<i>o</i> -CH ₃ C ₆ H ₄ CO)C ₆ H ₄ CO ₂ H (47 g.)	39
Phthalic anhydride	2-CH ₃ C ₆ H ₄ MgBr	2-(<i>o</i> -CH ₃ C ₆ H ₄ CO)C ₆ H ₄ CO ₂ H (74%)	40,41
Phthalic anhydride (14 g.)	4-CH ₃ C ₆ H ₄ MgBr (2 equiv.)	2-(<i>p</i> -CH ₃ C ₆ H ₄ CO) ₂ C ₆ H ₄ (1-2 g.); 3,3-di- (<i>p</i> -tolyl)phthalide; resin	37,32
Phthalic anhydride	2-CH ₃ OC ₆ H ₄ MgI (94 g. C ₇ H ₇ IO)	3,3-Di-(<i>o</i> -methoxyphenyl)phthalide	43
Phthalic anhydride	4-CH ₃ OC ₆ H ₄ MgBr	"Thick brown grease"	37
Phthalic anhydride	4-CH ₃ OC ₆ H ₄ MgBr (10% excess)	2-(<i>p</i> -CH ₃ OC ₆ H ₄ CO)C ₆ H ₄ CO ₂ H (70-80%)	33
Phthalic anhydride	4-CH ₃ OC ₆ H ₄ MgI	1,2-(<i>p</i> -CH ₃ OC ₆ H ₄ CO) ₂ C ₆ H ₄	45
Phthalic anhydride (18.7 g.)	3-Thianaphthenyl-MgBr (27 g. C ₈ H ₅ BrS)	3-(<i>o</i> -Carboxybenzoyl)thianaphthene (16 g.)	46
Phthalic anhydride (21 g.)	2,3-(CH ₃) ₂ C ₆ H ₃ MgBr (30 g. C ₈ H ₉ Br)	2-[2,3-(CH ₃) ₂ C ₆ H ₃ CO]C ₆ H ₄ CO ₂ H (25 g.)	44
Phthalic anhydride	3,5-(CH ₃) ₂ C ₆ H ₃ MgBr	2-[3,5-(CH ₃) ₂ C ₆ H ₃ CO]C ₆ H ₄ CO ₂ H (42.5%)	40

TABLE XI-I (Continued)

Anhydride	RMgX	Product(s)	Ref.
C₈H₄O₃ (cont.)			
Phthalic anhydride	1-C ₁₀ H ₇ MgBr (10% excess)	2- α -C ₁₀ H ₇ COC ₆ H ₄ CO ₂ H (70–80%)	33,47
Phthalic anhydride (0.16 mole)	1-C ₁₀ H ₇ MgBr (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	2- α -C ₁₀ H ₇ COC ₆ H ₄ CO ₂ H (57%)	11
Phthalic anhydride	2-C ₁₀ H ₇ MgBr (10% excess)	2- β -C ₁₀ H ₇ COC ₆ H ₄ CO ₂ H (70–80%); 3,3-di- β -naphthylphthalide	33,47
Phthalic anhydride (35.5 g.)	5-Tetralyl-MgBr (29.4 g. C ₁₀ H ₁₁ Br)	2-(5-Tetraloyl)benzoic acid (21 g., 54%)	48
Phthalic anhydride (0.5 mole)	C ₁₀ H ₁₇ MgCl* (0.5 mole)	2-(C ₁₀ H ₁₇ CO)C ₆ H ₄ CO ₂ H (95%)	49
Phthalic anhydride	4-CH ₃ C ₁₀ H ₆ -1-MgBr (10% excess)	2-(4-CH ₃ -1-C ₁₀ H ₆ CO)C ₆ H ₄ CO ₂ H	50
Phthalic anhydride (25 g.)	8-CH ₃ C ₁₀ H ₆ -1-MgBr (22 g. C ₁₁ H ₉ Br)	2-(8-CH ₃ -1-C ₁₀ H ₆ CO)C ₆ H ₄ CO ₂ H (19 g., 66%)	51
Phthalic anhydride (3.5 g.)	2-CH ₃ OC ₁₀ H ₆ -1-MgBr (6.8 g. C ₁₁ H ₉ BrO)	2-(2-CH ₃ O-1-C ₁₀ H ₆ CO)C ₆ H ₄ CO ₂ H	52
Phthalic anhydride	6-CH ₃ OC ₁₀ H ₆ -2-MgBr (10% excess)	2-(6-CH ₃ O-2-C ₁₀ H ₆)COC ₆ H ₄ CO ₂ H (70–80%)	33
Phthalic anhydride	9-Phenanthryl-MgBr (10% excess)	2-(9-Phenanthroyl)benzoic acid (70–80%)	33
Phthalic anhydride	9-Phenanthryl-MgBr	2-(9-Phenanthroyl)benzoic acid; 3,3-bis(9-phenanthryl)phthalide	53
C₈H₆O₃			
4,5-Dihydrophthalic anhydride (7.5 g.)	C ₆ H ₅ CH ₂ Cl (12.7 g.) + Mg (2.4 g.)	3,3-Dibenzyl-5,6-dihydrophthalide; (C ₆ H ₅ CH ₂ —) ₂	54
C₈H₈O₃			
1,4,5,6-Tetrahydrophthalic anhydride	CH ₃ MgI	3-Methyl-3a,4,5,6-tetrahydrophthalide	55
1,4,5,6-Tetrahydrophthalic anhydride	C ₂ H ₅ MgX	3-Ethyl-3a,4,5,6-tetrahydrophthalide	55
1,4,5,6-Tetrahydrophthalic anhydride (7.6 g.)	C ₆ H ₅ CH ₂ Cl (12.7 g.) + Mg (2.4 g.)	3,3-Dibenzyl-5,6,7,7a-tetrahydrophthalide; (C ₆ H ₅ CH ₂ —) ₂	54

* From pinene hydrochloride.

TABLE XI-I (Continued)

Anhydride	RMgX	Product(s)	Ref.
C₈H₁₆O₃			
Hexahydroisophthalic anhydride (15.4 g.)	CH ₃ MgI (from 31.2 g. iodide)	3-Acetylcyclohexanecarboxylic acid; (5.4 g.); dimethylhexahydroisophthalide (4.2 g.); 3-isopropylidenecyclohexane- carboxylic acid	8
Hexahydroisophthalic anhydride (7.7 g.)	CH ₃ MgI (from 7.8 g. iodide)	3-Acetylcyclohexanecarboxylic acid (>50%)	8
C₈H₁₄O₃			
(<i>n</i> -C ₃ H ₇ CO) ₂ O	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₃ H ₇ CO- <i>n</i> -C ₄ H ₉ (73%)	10
(<i>n</i> -C ₃ H ₇ CO) ₂ O	<i>i</i> -C ₄ H ₉ MgCl	<i>n</i> -C ₃ H ₇ CO- <i>i</i> -C ₄ H ₉ ; <i>n</i> -C ₃ H ₇ CO ₂ - <i>i</i> -C ₄ H ₉	21,16
(<i>n</i> -C ₃ H ₇ CO) ₂ O	<i>i</i> -C ₅ H ₁₁ MgCl (1 equiv.)	<i>n</i> -C ₃ H ₇ CO- <i>i</i> -C ₅ H ₁₁ ; <i>n</i> -C ₃ H ₇ CO ₂ - <i>i</i> -C ₅ H ₁₁	21,16
(<i>i</i> -C ₃ H ₇ CO) ₂ O	CH ₃ MgBr (1 equiv.)	CH ₃ CO- <i>i</i> -C ₃ H ₇	16
(<i>i</i> -C ₃ H ₇ CO) ₂ O	C ₂ H ₅ MgBr (1 equiv.)	C ₂ H ₅ CO- <i>i</i> -C ₃ H ₇	16
(<i>i</i> -C ₃ H ₇ CO) ₂ O (0.16 mole)	C ₆ H ₅ MgBr (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	<i>i</i> -C ₃ H ₇ COC ₆ H ₅ (72%)	11
C₉H₆O₃			
Homophthalic anhydride*	CH ₃ MgX (2 equiv.)	"Dimethylhomophthalide," m. 94-95°	60
Homophthalic anhydride* (5.0 g.)	CH ₃ MgI (4.7 ml. CH ₃ I)	1,1-Dimethyl-2,1-benzopyran-3(4 <i>H</i>)-one (1.9-2.3 g.); recovered anhydride (1.3-1.8 g.); homophthalic acid (0.4- 0.6 g.); residual oil (0.6-0.8 g.); CH ₄	56
Homophthalic anhydride*	C ₆ H ₅ MgX (2 equiv.)	"Diphenylhomophthalide," m. 160-161°	60
Homophthalic anhydride*	C ₆ H ₅ CH ₂ MgX (2 equiv.)	"Debenzylhomophthalide," m. 163-164°	60
3-Methylphthalic anhydride (8 g.)	C ₆ H ₅ MgBr (48 ml., 1.09 M)	3,3-Diphenyl-7-methylphthalide (3.7%); 2-C ₆ H ₅ CO-6-CH ₃ C ₆ H ₃ CO ₂ H (44%); 2-C ₆ H ₅ CO-3-CH ₃ C ₆ H ₃ CO ₂ H	39

* 2 1-Benzopyran-1,3(4*H*)-dione.

TABLE XI-I (Continued)

<u>Anhydride</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₆O₃ (cont.)			
3-Methylphthalic anhydride (5.3 g.)	C ₆ H ₅ MgBr (38 ml., 1.17 M)	3,3-Diphenyl-7-methylphthalide (3.5 g., 53%)	39
3-Methylphthalic anhydride (16 g.)	2-CH ₃ C ₆ H ₄ MgBr (100 ml., 0.98 M)	2- <i>o</i> -Toluyyl-6-methylbenzoic acid (11.57 g., 46.9%); 2- <i>o</i> -toluyyl-3-methylbenzoic acid (1.31 g., 5.3%)	39
3-Methylphthalic anhydride (16.2 g.)	1-C ₁₀ H ₇ MgBr (23 g. C ₁₀ H ₇ Br)	6- α -Naphthoyl- <i>o</i> -toluic acid (15.2 g., 52%); 2- α -naphthoyl- <i>m</i> -toluic acid (0.45 g., 1.5%)	61
C₉H₆O₄			
4-Methoxyphthalic anhydride	C ₂ H ₅ MgBr (2 equiv.)	3,3-Diethyl-6-methoxyphthalide	62
4-Methoxyphthalic anhydride	C ₆ H ₅ MgBr (10% excess)	2-C ₆ H ₅ CO-4(5?)-CH ₃ OC ₆ H ₃ CO ₂ H (70-80%)	33
4-Methoxyphthalic anhydride	1-C ₁₀ H ₇ MgBr (10% excess)	2- α -C ₁₀ H ₇ CO-4(5?)-CH ₃ OC ₆ H ₃ CO ₂ H (70-80%)	33
C₉H₁₂O₃			
Apocamphoric anhydride (16.8 g.)	CH ₃ MgI (15.6 g. CH ₃ I)	2,2-Dimethyl-3-acetyl-1-cyclopentane-carboxylic acid ("poor yield")	63
Apocamphoric anhydride (8.4 g.)	CH ₃ MgI (15.6 g. CH ₃ I)	4,4,8,8-Tetramethyl-3-oxabicyclo[3.2.1]octan-2-one; 2,2-dimethyl-3-iso-propylidene-1-cyclopentanecarboxylic acid	63
Santenic anhydride (8.4 g.)	CH ₃ MgI (7.8 g. CH ₃ I)	2,3-Dimethyl-3-acetyl-1-cyclopentane-carboxylic acid	63
Santenic anhydride (8.4 g.)	CH ₃ MgI (17.0 g. CH ₃ I)	"Dimethylsantolide" (<i>i.e.</i> , 1,4,4,8-tetramethyl-3-oxabicyclo[3.2.1]octan-2-one or 1,2,2,8-tetramethyl-3-oxabicyclo[3.2.1]octan-4-one); an unsat'd acid	63

TABLE XI-I (Continued)

Anhydride	RMgX	Product(s)	Ref.
C₁₀H₈O₃			
Phenylsuccinic anhydride (8.7 g.)	C ₆ H ₅ MgBr (5.5 ml. C ₆ H ₅ Br)	α, γ, γ-Triphenyl-γ-butyrolactone (1.2 g.)	13
Phenylsuccinic anhydride (17.6 g.)	1-C ₁₀ H ₇ MgBr (21.0 g. C ₁₀ H ₇ Br)	α-Phenyl-γ, γ-di-1-naphthyl-γ-butyrolactone; HO ₂ CCH(C ₆ H ₅)CHCO ₂ H (2 g.) (after red'n of acidic fraction with amalg. Zn)	13
3,4-Dimethylphthalic anhydride (20.0 g.)	2,3-(CH ₃) ₂ C ₆ H ₃ MgBr (20.0 g. C ₈ H ₉ Br)	2-(2,3-Dimethylbenzoyl)-3,4-dimethylbenzoic acid (2.4 g., 8%); 2-(2,3-dimethylbenzoyl)-5,6-dimethylbenzoic acid (9.0 g., 30%)	75
3,6-Dimethylphthalic anhydride	C ₆ H ₅ MgBr	2-C ₆ H ₅ CO-3,6-(CH ₃) ₂ C ₆ H ₂ CO ₂ H (81%)	64
3,6-Dimethylphthalic anhydride	2,4-(CH ₃) ₂ C ₆ H ₃ MgBr	2-[2,4-(CH ₃) ₂ C ₆ H ₃ CO]-3,6-(CH ₃) ₂ C ₆ H ₂ CO ₂ H (55%); recovered anhydride (31%)	64
3,6-Dimethylphthalic anhydride	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	2-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CO]-3,6-(CH ₃) ₂ C ₆ H ₂ CO ₂ H (27%); recovered anhydride (33%)*	64
3,6-Dimethylphthalic anhydride	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	2-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CO]-3,6-(CH ₃) ₂ C ₆ H ₂ CO ₂ H (44%); recovered anhydride (22%)†	64
C₁₀H₈O₅			
Hemipinic anhydride (2 g.)	C ₆ H ₅ MgBr (1.1 ml. C ₆ H ₅ Br)	2-C ₆ H ₅ CO-3,4-(CH ₃ O) ₂ C ₆ H ₂ CO ₂ H	52
Hemipinic anhydride	1-C ₁₀ H ₇ MgBr	2-α-C ₁₀ H ₇ CO-3,4-(CH ₃ O) ₂ C ₆ H ₂ CO ₂ H	52
Hemipinic anhydride	6-CH ₃ OC ₁₀ H ₆ -2-MgBr	2-(6-CH ₃ O-2-C ₁₀ H ₆ CO)3,4-(CH ₃ O) ₂ -C ₆ H ₂ CO ₂ H	52
C₁₀H₁₄O₃			
Camphoric anhydride (18.2 g.)	CH ₃ MgI (24.8 g. CH ₃ I)	3,3-Dimethylcampholide (1,4,4,8,8-pentamethyl-3-oxabicyclo[3.2.1]octan-2-one) (3 g.); camphoric acid; recovered anhydride	66

* Refluxed two hours in Et₂O.† Refluxed one hour in C₆H₆.

TABLE XI-I (Continued)

<u>Anhydride</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₄O₃ (cont.)			
(+)-Camphoric anhydride (18.2 g.)	CH ₃ MgI (17.0 g. CH ₃ I)	2,2,3-Trimethyl-3-acetyl-1-cyclopentanecarboxylic acid	63
(+)-Camphoric anhydride (18.2 g.)	CH ₃ MgI (34.0 g. CH ₃ I)	2,2,3-Trimethyl-3-acetyl-1-cyclopentanecarboxylic acid; 3,3-dimethylcampholide (1,4,4,8,8-pentamethyl-3-oxabicyclo[3.2.1]octan-2-one); 1,2,2-trimethyl-3-isopropenyl-1-cyclopropanecarboxylic acid	63
(+)-Camphoric anhydride (18.2 g.)	C ₆ H ₅ CH ₂ MgCl (27.9 g. C ₇ H ₇ Cl)	A dibenzylmethylenetrimethylcyclopentanecarboxylic acid and a phenylacetyltrimethylcyclopentanecarboxylic acid of undetermined constitution	63; <i>cf.</i> 9
C₁₀H₁₄O₄			
Cineolic anhydride (50 g.)	CH ₃ MgX* (16.5 g. Mg)	2,2,6-Trimethyl-6-(1-hydroxyisopropyl)tetrahydropyran-3-carboxylic acid (50 g., 27%)	65
Cineolic anhydride (80 g.)	C ₂ H ₅ MgBr (110 g. C ₂ H ₅ Br)	2,2,6-Trimethyl-6-(1-hydroxy-1-ethylpropyl)tetrahydropyran-3-carboxylic acid (90 g., 92%)	65
Cineolic anhydride (15.0 g.)	<i>n</i> -C ₃ H ₇ MgBr (23.5 g. C ₃ H ₇ Br)	2,2,6-Trimethyl-6-(1-hydroxy-1-propylbutyl)tetrahydropyran-3-carboxylic acid (6 g.); 2,2,6-trimethyl-6-(1-hydroxybutyl)tetrahydropyran-6-carboxylic acid (8 g.)	65
Cineolic anhydride (15.0 g.)	<i>i</i> -C ₃ H ₇ MgBr (23.5 g. C ₃ H ₇ Br)	2,2,6-Trimethyl-6-(1-hydroxyisobutyl)tetrahydropyran-3-carboxylic acid (87%)	65

* X = Br, I.

TABLE XI-I (Continued)

<u>Anhydride</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₄O₄ (<i>cont.</i>)			
Cineolic anhydride (90 g.)	C ₆ H ₅ MgBr (180 g. C ₆ H ₅ Br)	2,2,6-Trimethyl-6-(α -hydroxy-benzhydryl)tetrahydropyran-3-carboxylic acid (142 g., 88%, crude)*	65
Cineolic anhydride (17 g.)	C ₆ H ₅ MgBr (16 g. C ₆ H ₅ Br)	Cineolic acid (5 g.); 2,2,6-trimethyl-6-(α -hydroxybenzhydryl)tetrahydropyran-3-carboxylic acid (15.5 g.) [†]	65
Cineolic anhydride (20 g.)	(CH ₂) ₅ CHMgBr (59 g. C ₆ H ₁₁ Br)	2,2,6-Trimethyl-6-cyclohexylhydroxymethyltetrahydropyran-3-carboxylic acid (22 g., 78%)	65
Cineolic anhydride (22 g.)	C ₆ H ₅ CH ₂ MgCl (52 g. C ₇ H ₇ Cl)	2,2,6-Trimethyl-6-(1-hydroxy-2,2'-diphenylisopropyl)tetrahydropyran-3-carboxylic acid (32 g., 84%)	65
Cineolic anhydride (6 g.)	4-CH ₃ C ₆ H ₄ MgBr (25.7 g. C ₇ H ₇ Br)	2,2,6-Trimethyl-6-(α -hydroxy-4,4'-dimethylbenzhydryl)tetrahydropyran-3-carboxylic acid (10 g., 88%)	65
Cineolic anhydride (5 g.)	1-C ₁₀ H ₇ MgBr (42 g. C ₁₀ H ₇ Br)	2,2,6-Trimethyl-6-di- α -naphthylhydroxymethyl)tetrahydropyran-3-carboxylic acid (10 g., 88%)	65
C₁₀H₁₈O₃ (<i>i</i> -C ₄ H ₉ CO) ₂ O	<i>i</i> -C ₄ H ₉ MgCl	(<i>i</i> -C ₄ H ₉) ₂ CO	21,16
C₁₂H₆O₃ 1,2-Naphthalenedicarboxylic anhydride (19.8 g.)	2-ClC ₆ H ₄ MgBr (21.1 g. C ₆ H ₄ BrCl)	2-(<i>o</i> -ClC ₆ H ₄ CO)C ₁₀ H ₆ -1-CO ₂ H (13.3 g., 43%)	67

* Slow dropwise addition of Et₂O-anhydride solution to stirred Grignard reagent solution; one to two hours stirring; overnight standing.

[†] Addition of cooled (-15°) Grignard reagent solution to stirred Et₂O-anhydride solution at -15° to -10° .

TABLE XI-I (Continued)

<u>Anhydride</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₆O₃ (<i>cont.</i>)			
1,2-Naphthalenedicarboxylic anhydride (19.8 g.)	4-ClC ₆ H ₄ MgBr (21.1 g. C ₆ H ₄ BrCl)	2-(<i>p</i> -ClC ₆ H ₄ CO)C ₁₀ H ₆ -1-CO ₂ H (9.7 g., 31%); 1-(<i>p</i> -ClC ₆ H ₄ CO)C ₁₀ H ₆ -2-CO ₂ H (2.9 g., 10%)	68
1,2-Naphthalenedicarboxylic anhydride	C ₆ H ₅ MgBr	2-C ₆ H ₅ COC ₁₀ H ₆ -1-CO ₂ H (30%)	69
1,2-Naphthalenedicarboxylic anhydride (20 g.)	2-CH ₃ C ₆ H ₄ MgBr (19 g. C ₇ H ₇ Br)	2-(<i>o</i> -CH ₃ C ₆ H ₄ CO)C ₁₀ H ₆ -1-CO ₂ H (11-12.5 g., 38-43%); 1-(<i>o</i> -CH ₃ C ₆ H ₄ CO)C ₁₀ H ₆ -2-CO ₂ H (1 g., 3%)	69
1,2-Naphthalenedicarboxylic anhydride (33.3 g.)	2-CH ₃ OC ₆ H ₄ MgBr (140 cc., 1.2 M)	2-(<i>o</i> -CH ₃ OC ₆ H ₄ CO)C ₁₀ H ₆ -1-CO ₂ H (13%); 1-(<i>o</i> -CH ₃ OC ₆ H ₄ CO)C ₁₀ H ₆ -2-CO ₂ H (13%); 3,3-di-(<i>o</i> -methoxyphenyl)-6,7-benzophthalide (17%); recovered anhydride	70
1,2-Naphthalenedicarboxylic anhydride (29.7 g.)	2,3-(CH ₃) ₂ C ₆ H ₃ MgBr (30.0 g. C ₈ H ₉ Br)	2-[2,3-(CH ₃) ₂ C ₆ H ₃ CO]C ₁₀ H ₆ -1-CO ₂ H (10.8 g.)	44
1,2-Naphthalenedicarboxylic anhydride (15.0 g.)	1-C ₁₀ H ₇ MgBr (20.4 g. C ₁₀ H ₇ Br)	2- α -C ₁₀ H ₇ COC ₁₀ H ₆ -1-CO ₂ H (11.3 g., 45.8%); 1- α -C ₁₀ H ₇ COC ₁₀ H ₆ -2-CO ₂ H	57
2,3-Naphthalenedicarboxylic anhydride	C ₆ H ₅ MgBr (10% excess)	3-C ₆ H ₅ COC ₁₀ H ₆ -2-CO ₂ H (70-80%)	33
2,3-Naphthalenedicarboxylic anhydride	4-CH ₃ OC ₆ H ₄ MgBr	3-(<i>p</i> -CH ₃ OC ₆ H ₄ CO)C ₁₀ H ₆ -3-CO ₂ H (70-80%)	33
2,3-Naphthalenedicarboxylic anhydride	1-C ₁₀ H ₇ MgBr (10% excess)	3-(α -C ₁₀ H ₇ CO)C ₁₀ H ₆ -2-CO ₂ H (70-80%)	33
2,3-Naphthalenedicarboxylic anhydride	2-C ₁₀ H ₇ MgBr (10% excess)	3-(β -C ₁₀ H ₇ CO)C ₁₀ H ₆ -2-CO ₂ H (70-80%)	33
Naphthalic anhydride (10 g.)	2-CH ₃ C ₆ H ₄ MgBr	8-(<i>o</i> -CH ₃ C ₆ H ₄)C ₁₀ H ₆ -1-CO ₂ H (70%)	5
Naphthalic anhydride (12 g.)	1-C ₁₀ H ₇ MgBr (17 g. C ₁₀ H ₇ Br)	8-(α -C ₁₀ H ₇ CO)C ₁₀ H ₆ -1-CO ₂ H (65%)	5
C₁₄H₈O₃			
3-Phenylphthalic anhydride (5 g.)	C ₆ H ₅ MgBr (2.6 ml. C ₆ H ₅ Br)	2-C ₆ H ₅ -6-C ₆ H ₅ COC ₆ H ₃ CO ₂ H; 2-C ₆ H ₅ CO-3-C ₆ H ₅ C ₆ H ₃ CO ₂ H	58

TABLE XI-I (Continued)

<u>Anhydride</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₆O₃ (<i>cont.</i>)			
Diphenic anhydride	C ₆ H ₅ MgBr (2.5 equiv.)	2-[HO(C ₆ H ₅) ₂ C]C ₆ H ₄ C ₆ H ₄ -2-CO ₂ H	4
C₁₄H₁₀O₃			
(C ₆ H ₅ CO) ₂ O	CH ₃ MgI	C ₆ H ₅ (CH ₃) ₂ COH	15
(C ₆ H ₅ CO) ₂ O (0.16 mole)	C ₂ H ₅ MgBr (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	C ₂ H ₅ COC ₆ H ₅ (53%)	11
(C ₆ H ₅ CO) ₂ O (0.16 mole)	<i>i</i> -C ₃ H ₇ MgBr (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	<i>i</i> -C ₃ H ₇ COC ₆ H ₅ (47%)	11
(C ₆ H ₅ CO) ₂ O (0.16 mole)	<i>i</i> -C ₃ H ₇ MgI (7.3 g., 0.3 g.-atom Mg) + CdCl ₂ (31.2 g., 0.17 mole)	<i>i</i> -C ₃ H ₇ COC ₆ H ₅ (33%)	11
(C ₆ H ₅ CO) ₂ O (47.5 g., 0.21 mole)	<i>t</i> -C ₄ H ₉ MgCl (14.5 g. Mg) + CdCl ₂ (56.8 g., 0.31 mole)	<i>t</i> -C ₄ H ₉ COC ₆ H ₅ (40%)	11
(C ₆ H ₅ CO) ₂ O	C ₆ H ₅ MgBr (0.5 equiv.)	(C ₆ H ₅) ₂ CO (75-87%)	10
(C ₆ H ₅ CO) ₂ O (16 g.)	2,5-Diphenyl-3-furyl-MgBr (19 g. C ₁₆ H ₁₁ OBr)	2,5-Diphenyl-3-benzoylfuran (13 g., 65%)	74
C₁₄H₁₂O₃			
3-Phenyl-1,2,3,4-tetrahydrophthalic anhydride (7.6 g.)	C ₆ H ₅ MgBr (3.5 ml. C ₆ H ₅ Br)	3,3,7-Triphenyl-3a,4,7,7a-tetrahydro- phthalide; unidentified acidic products	13
C₁₄H₂₆O₃			
(<i>n</i> -C ₆ H ₁₃ CO) ₂ O	CH ₃ MgBr (1 equiv.)	CH ₃ CO- <i>n</i> -C ₆ H ₁₃	16
(<i>n</i> -C ₆ H ₁₃ CO) ₂ O	C ₂ H ₅ MgBr (1 equiv.)	C ₂ H ₅ CO- <i>n</i> -C ₆ H ₁₃ ; <i>n</i> -C ₆ H ₁₃ CO ₂ C ₂ H ₅	16
C₁₆H₈O₃			
9,10-Phenanthrenedicarboxylic anhydride (0.7 g.)	C ₆ H ₅ MgBr (0.44 g. C ₆ H ₅ Br)	9-Benzoyl-10-phenanthrenedicarboxylic acid	53

TABLE XI-I (Continued)

<u>Anhydride</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₀H₁₂O₃			
3,6-Diphenylphthalic anhydride	4-BrC ₆ H ₄ MgBr	2-(<i>p</i> -BrC ₆ H ₄ CO)-3,6-(C ₆ H ₅) ₂ C ₆ H ₂ CO ₂ H	58
3,6-Diphenylphthalic anhydride (6.00 g.)	C ₆ H ₅ MgBr (2.14 g. C ₆ H ₅ Br)	2-C ₆ H ₅ CO-3,6-(C ₆ H ₅) ₂ C ₆ H ₂ CO ₂ H (50%)	58
3,6-Diphenylphthalic anhydride (15 g.)	4-CH ₃ OC ₆ H ₄ MgBr (28 g. C ₇ H ₇ BrO)	2-(<i>p</i> -CH ₃ OC ₆ H ₄ CO)-3,6-(C ₆ H ₅) ₂ C ₆ H ₂ CO ₂ H	58
3,6-Diphenylphthalic anhydride (15.0 g.)	1-C ₁₀ H ₇ MgBr (10.3 g. C ₁₀ H ₇ Br)	2-(α -C ₁₀ H ₇ CO)-3,6-(C ₆ H ₅) ₂ C ₆ H ₂ CO ₂ H (50%)	58
3,6-Diphenylphthalic anhydride (15 g.)	6-CH ₃ OC ₁₀ H ₆ -2-MgBr (15 g. C ₁₁ H ₉ BrO)	2-(6-CH ₃ OC ₁₀ H ₆ -2-CO)-3,6-(C ₆ H ₅) ₂ C ₆ H ₂ CO ₂ H	58
C₂₀H₂₂O₃			
Mesitoic anhydride (1.0 g.)	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (8.8 g. C ₉ H ₁₁ Br)	[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ CO	59

REFERENCES FOR TABLE XI-I

- (1) Diels and Reinbeck, *Ber.*, 43, 1271-9 (1910).
- (2) Weizmann and Bergmann, *J. Am. Chem. Soc.*, 60, 2647-50 (1938).
- (3) Purdie and Arup, *J. Chem. Soc.*, 97, 1537-46 (1910).
- (4) Ssergejew, *J. Russ. Phys.-Chem. Soc.*, 61, 1421-49 (1929); *Chem. Zentr.*, 1930,II, 391.
- (5) Weiss and Fastmann, *Monatsh.*, 47, 727-32 (1926).
- (6) Cason, *J. Am. Chem. Soc.*, 64, 1106-10 (1942).
- (7) Cason and Prout, *J. Am. Chem. Soc.*, 66, 46-50 (1944).
- (8) Komppa and Rohrmann, *Ann.*, 509, 259-68 (1934).
- (9) Houben and Hahn, *Ber.*, 41, 1580-8 (1908).
- (10) Newman and Smith, *J. Org. Chem.*, 13, 592-8 (1948).
- (11) Benneville, *J. Org. Chem.*, 6, 462-6 (1941).
- (12) Stefanova, *Annuaire univ. Sofia, Faculté phys.-math.*, 40, Livre 2, 147-66 (1943-44); *Chem. Abstr.*, 42, 4156 (1948).
- (13) Weizmann, Blum-Bergmann, and Bergmann, *J. Chem. Soc.*, 1935, 1370-1.
- (14) Austin and Johnson, *J. Am. Chem. Soc.*, 54, 647-60 (1932).
- (15) Tissier and Grignard, *Compt. rend.*, 132, 336-8 (1901); *Chem. Zentr.*, 1901,I, 930; *J. Chem. Soc.*, 80,I, 316 (1901).
- (16) Fournier, *Bull. soc. chim.*, [4], 7, 836-40 (1910).
- (17) Mingoia, *Gazz. chim. ital.*, 61, 449-58 (1931); *Chem. Abstr.*, 26, 453 (1932).
- (18) Newman and Booth, *J. Am. Chem. Soc.*, 67, 154 (1945).
- (19) Sweet and Marvel, *J. Am. Chem. Soc.*, 54, 1184-90 (1932).
- (20) Nazarov and Elizarova, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1940, 189-94; *Chem. Abstr.*, 36, 741 (1942).
- (21) Fournier, *Bull. soc. chim.*, [3], 35, 14 (1906).
- (22) Brokaw and Brode, *J. Org. Chem.*, 13, 194-9 (1948).
- (23) Kroeger and Nieuwland, *J. Am. Chem. Soc.*, 58, 1861-3 (1936).
- (24) Kitchin and Sandin, *J. Am. Chem. Soc.*, 67, 1645-6 (1945).
- (25) Newman and O'Leary, *J. Am. Chem. Soc.*, 68, 258-61 (1946).
- (26) Cason, *J. Am. Chem. Soc.*, 68, 2078-81 (1946).
- (27) Tarbell, *J. Am. Chem. Soc.*, 60, 215-6 (1938).
- (28) Tarbell and Weaver, *J. Am. Chem. Soc.*, 62, 2747-50 (1940).
- (29) Ellingboe and Fuson, *J. Am. Chem. Soc.*, 56, 1777-9 (1934).
- (30) Mazza, *Rend. accad. sci. fis. mat., Napoli ser. 3a*, 34, 59-65 (1928); *Chem. Zentr.*, 1929,I, 1826.
- (31) Cobb, *Am. Chem. J.*, 35, 486-508 (1906).
- (32) Bauer, *Arch. Pharm.*, 247, 220-5 (1909); *Chem. Zentr.*, 1909,II, 525.
- (33) Weizmann, Bergmann, and Bergmann, *J. Chem. Soc.*, 1935, 1367-70.
- (34) Bauer, *Ber.*, 37, 735-7 (1904).
- (35) Orlov, *J. Russ. Phys.-Chem. Soc.*, 44, 1868-70 (1912); *Chem. Abstr.*, 7, 1174 (1913).
- (36) Pickles and Weizmann, *Chem. News*, 90, 276 (1904).
- (37) Bauer, *Ber.*, 38, 240-1 (1905).
- (38) Vène and Gérard, *Compt. rend.*, 222, 1115-7 (1946); *Chem. Abstr.*, 40, 5715 (1946).
- (39) Newman and McCleary, *J. Am. Chem. Soc.*, 63, 1537-41 (1941).
- (40) Fieser and Heymann, *J. Am. Chem. Soc.*, 64, 376-82 (1942).
- (41) Scholl and Donat, *Ber.*, 64B, 318-21 (1931).
- (42) Fournier, *Bull. soc. chim.*, [3], 31, 483 (1904).
- (43) Ferrario, *Gazz. chim. ital.*, 41,I, 1-11 (1911); *Chem. Zentr.*, 1911,I, 1059.
- (44) Badger, Cook, and Goulden, *J. Chem. Soc.*, 1940, 16-8.

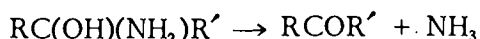
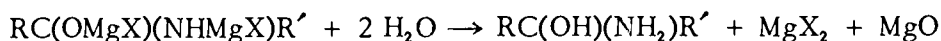
- (45) Blicke and Weinkauff, *J. Am. Chem. Soc.*, 54, 1454-9 (1932).
- (46) Komppa, *Kgl. Norske Videnskab. Selskabs, Forh.*, 9, 157-60 (1936); *Chem. Abstr.*, 31, 7423 (1937); *Chem. Zentr.*, 1937,II, 391.
- (47) Pickles and Weizmann, *Proc. Chem. Soc.*, 20, 201 (1904).
- (48) Fieser and Hershberg, *J. Am. Chem. Soc.*, 59, 2331-5 (1937).
- (49) Bousset, *Bull. soc. chim.*, [5], 2, 2182-7 (1935).
- (50) Cook and Robinson, *J. Chem. Soc.*, 1938, 505-13.
- (51) Fieser and Seligman, *J. Am. Chem. Soc.*, 61, 136-42 (1939).
- (52) Weizmann and Bergmann, *J. Chem. Soc.*, 1936, 567-9.
- (53) Weizmann, Bergmann, and Berlin, *J. Am. Chem. Soc.*, 60, 1331-4 (1938).
- (54) Berlingozzi, *Gazz. chim. ital.*, 61, 886-97 (1932); *Chem. Abstr.*, 26, 2728 (1932).
- (55) Berlingozzi and Mazza, *Gazz. chim. ital.*, 56, 88-98 (1926); *Chem. Zentr.*, 1926,II, 401.
- (56) Price, Lewis, and Meister, *J. Am. Chem. Soc.*, 61, 2760-2 (1939).
- (57) Fieser and Kilmer, *J. Am. Chem. Soc.*, 61, 862-4 (1939).
- (58) Weizmann, Bergmann, and Haskelberg, *J. Chem. Soc.*, 1939, 391-7.
- (59) Fuson, Corse, and Rabjohn, *J. Am. Chem. Soc.*, 63, 2852-3 (1941).
- (60) Bauer and Wölz, *Arch. Pharm.*, 249, 454-8 (1911); *Chem. Zentr.*, 1911,II, 1221.
- (61) Newman, *J. Am. Chem. Soc.*, 59, 1003-6 (1937).
- (62) Bauer, *Arch. Pharm.*, 249, 450-3 (1911); *Chem. Zentr.*, 1911,II, 1220.
- (63) Komppa and Rohrmann, *Ann.*, 521, 227-42 (1936).
- (64) Newman and Lord, *J. Am. Chem. Soc.*, 66, 733-5 (1944).
- (65) Rupe and Zweidler, *Helv. Chim. Acta*, 23, 1025-45 (1940).
- (66) Komppa, *Ber.*, 41, 1039-41 (1908).
- (67) Newman, *J. Am. Chem. Soc.*, 60, 1368-70 (1938).
- (68) Newman and Orchin, *J. Am. Chem. Soc.*, 60, 586-9 (1938).
- (69) Fieser and Newman, *J. Am. Chem. Soc.*, 58, 2376-82 (1936).
- (70) Newman and Wise, *J. Am. Chem. Soc.*, 63, 2109-11 (1941).
- (71) Heilbron, *J. Chem. Soc.*, 1948, 386-93.
- (72) Heilbron, Jones, and Richardson, *J. Chem. Soc.*, 1949, 287-93.
- (73) Sobotka and Chanley, *J. Am. Chem. Soc.*, 70, 3914-8 (1948).
- (74) Lutz and Smith, *J. Am. Chem. Soc.*, 63, 1148-50 (1941).
- (75) Nichol and Sandin, *J. Am. Chem. Soc.*, 69, 2256-8 (1947).
- (76) Gaertner, *J. Am. Chem. Soc.*, 73, 3934-7 (1951).

CHAPTER XII

Reactions of Grignard Reagents with Carboxylic Amides Imides, and Lactams

KETONE OR ALDEHYDE FORMATION (FROM AMIDES)

The amide-Grignard reagent reaction that is usually regarded as "normal" is that originally reported by Béï's,¹ which he described as follows:



Actually, little or nothing concerning the mechanism of the reaction is known. In general the yields obtained are not such as to recommend the reaction as a preparative method. For the amides investigated by Béï's (propionamide, butyramide, isovaleramide, and benzamide), 20-50 percent yields of ketone were obtained from methylmagnesium iodide, ethylmagnesium iodide, and ethylmagnesium bromide reactions. The yields tended to be higher for the amides of higher molecular weight. Acetamide gave meagre yields of methyl ketones, and formamide produced no aldehyde at all.

Aldehydes have, however, been obtained in varying yields from *N,N*-disubstituted formamides investigated by Bouveault² and others (see Table XII-I).



NITRILE FORMATION (FROM AMIDES)

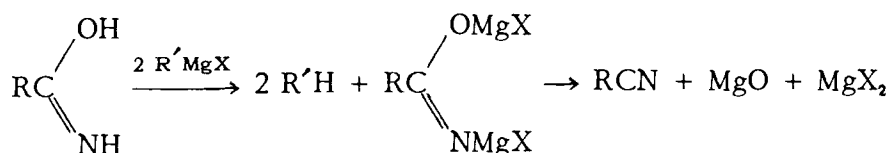
Relatively few cases of nitrile formation have been reported. However, in view of the facts that nitriles might be expected to react further with an excess of Grignard reagent to yield ketimines (or the corresponding ketones) and that most investigators have made no attempt to isolate nitriles, this is scarcely surprising. It is altogether possible that in some instances the reported "normal" product (ketone) is obtained by way of the nitrile.

¹Béï's, *Compt. rend.*, 137, 575-6 (1903); *Chem. Zentr.*, 1903,11, 1110.

²Bouveault, *Bull. soc. chim.*, [3], 31, 1322-7 (1904).

On the basis of a rather small number of cases examined, Ramart *et al.*³ have generalized as follows. With phenylmagnesium bromide, α -mono- and α,α -disubstituted acetamides react to give ketones, but α,α,α -trisubstituted acetamides give nitriles. Of the latter, those of the types $\text{AlkAr}_2\text{CCONH}_2$ and $\text{ArAlk}_2\text{CCONH}_2$ give nitriles almost exclusively; those of the type $\text{Alk}_3\text{CCONH}_2$ give a preponderance of ketone, but with some nitrile.

Ramart *et al.* have accounted for nitrile formation on the assumption that reaction takes place with the imido form.



Specific examples of acetamides said to give nitriles exclusively (with phenylmagnesium bromide) are: α -methyl- α -ethyl- α -phenyl-, α,α -diethyl- α -phenyl-, and α -benzyl- α,α -diphenyl-. Fencholamide and "dimethylcampholamide" are said to react similarly. α,α -Dimethyl- α -benzylacetamide is reported to give nitrile as the principle product, together with some ketone. α,α -Dimethyl- α -ethyl- and α,α,α -trimethylacetamides gave the respective ketones chiefly, together with a little of the respective nitriles.

Bruzau⁴ has also isolated nitriles as byproducts of the reactions of α -phenylpropionamide with aryl Grignard reagents, and Fries and Schimmelschmidt⁵ report 2-methoxy-3-naphthonitrile as the product of the reaction of 2-methoxy-3-naphthamide with methylmagnesium iodide.

AMINE FORMATION (FROM AMIDES)

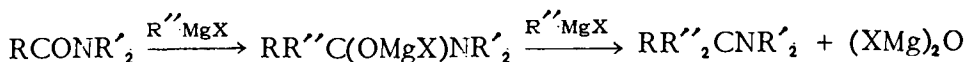
In exploring the possibilities of aldehyde preparation by reactions of Grignard reagents with *N,N*-dialkylated formamides, Bouveault (*loc. cit.*³) obtained, as a byproduct of the reaction of isoamylmagnesium chloride with *N,N*-dimethylformamide, some 2,8-dimethyl-5-dimethylaminononane [$(i\text{-C}_5\text{H}_{11})_2\text{CHN}(\text{CH}_3)_2$]. The available data are scarcely extensive enough to support any generalizations concerning the necessary and sufficient requirements for this type of reaction, but all instances so far reported have involved amides of the type RCONR'_2 in which R may be H or a hydrocarbon radical.

On the whole it seems probable that the reaction is a stepwise phenomenon of which the more significant portions may be summarized as follows:

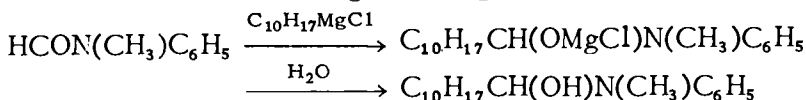
³Ramart-Lucas, Laclôte, and Anagnostopoulis, *Compt. rend.*, 185, 282-4 (1927); *Chem. Zentr.*, 1927, II, 1566; *Chem. Abstr.*, 21, 3359 (1927).

⁴Bruzau, *Ann. chim.*, [11], 1, 257-358 (1934).

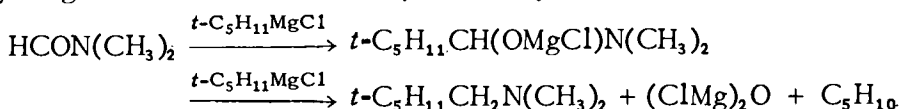
⁵Fries and Schimmelschmidt, *Ber.*, 58B, 2835-45 (1925).



If, for steric or other reasons, the final step failed of realization one might expect as product an amino alcohol. This might possibly account for the product obtained by Houben and Doescher⁶ from the reaction of *N*-methylformanilide with the Grignard reagent of pinene hydrochloride.



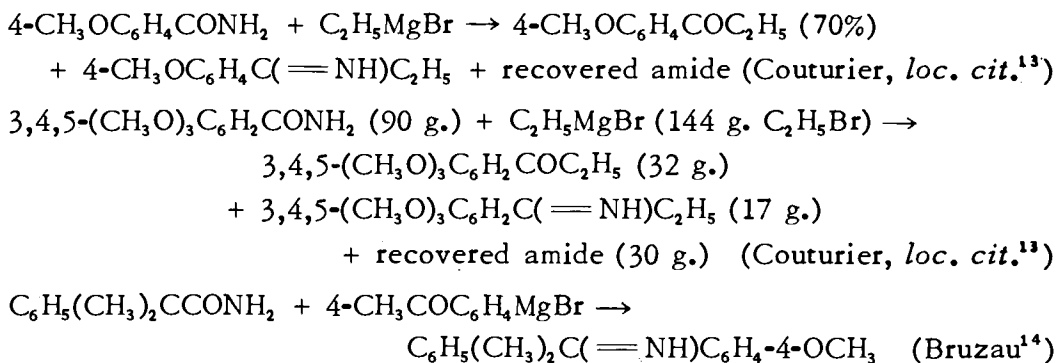
It is also conceivable that the final step might be, in some cases, a disproportionation rather than a simple metathesis. This would account for the products observed by Bouveault (*loc. cit.*²) in the reaction of *t*-amylmagnesium chloride with *N,N*-dimethylformamide.



Some examples of reactant pairs which appear to follow, at least in part, the reaction sequence first suggested are: $\text{HCON(C}_2\text{H}_5\text{)}_2$, $\text{CH}_3\text{C}\equiv\text{CMgBr}$ (Viguiér⁷); $\text{HCON(C}_2\text{H}_5\text{)}_2$, $\text{C}_2\text{H}_5\text{MgX}$ (Maxim⁸); $\text{HCON(C}_2\text{H}_5\text{)}_2$, $n\text{-C}_3\text{H}_7\text{MgBr}$ (Maxim and Mavrodineanu⁹); $\text{HCON(CH}_3\text{)}_2$, RMgX (Maxim and Mavrodineanu¹⁰); $n\text{-C}_3\text{H}_7\text{CONRR}'$, $\text{R}''\text{MgX}$ (Montagne¹¹); $\text{C}_6\text{H}_5\text{CON(C}_2\text{H}_5\text{)C}_6\text{H}_5$, $\text{C}_6\text{H}_5\text{MgBr}$ (Busch and Fleischmann¹²); $4\text{-CH}_3\text{OC}_6\text{H}_4\text{CON(C}_2\text{H}_5\text{)}_2$, RMgBr (Couturier¹³). Other examples are to be found in Table XII-I.

IMINE FORMATION (FROM AMIDES)

In a few instances imines have been reported among the products of reactions of amides with Grignard reagents. For example:



⁶Houben and Doescher, *Ber.*, 40, 4576-9 (1907).

⁷Viguiér, *Compt. rend.*, 153, 955-7 (1911); *Chem. Zentr.*, 1912, 1, 20.

⁸Maxim, *Bull. soc. chim.*, [4], 41, 809-13 (1927).

⁹Maxim and Mavrodineanu, *Bull. soc. chim.*, [5], 2, 591-600 (1935).

¹⁰Maxim and Mavrodineanu, *Bull. soc. chim.*, [5], 3, 1084-93 (1936).

¹¹Montagne, *Compt. rend.*, 183, 216-8 (1926).

¹²Busch and Fleischmann, *Ber.*, 43, 2553-6 (1910).

¹³Couturier, *Compt. rend.*, 205, 800-2 (1937); *Ann. chim.*, [11], 10, 559-629 (1938).

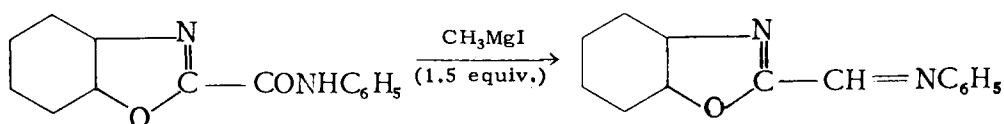
¹⁴Bruzau, *Compt. rend.*, 194, 1662-4 (1932).

Conceivably imine formation could result in these cases from further reaction of an intermediate nitrile. It seems equally probable, however, that it might result from a reaction akin to a dehydration.



In a case reported by Montagne and Rousseau,¹⁵ intermediate nitrile formation would be impossible, and it is necessary to assume a reaction of the "dehydration" type. Upon treatment of propionanilide with an excess of ethylmagnesium bromide they obtained as one of the products the anil of 3-pentanone (*ca.* 40 percent yield). Butyranilide reacted similarly.

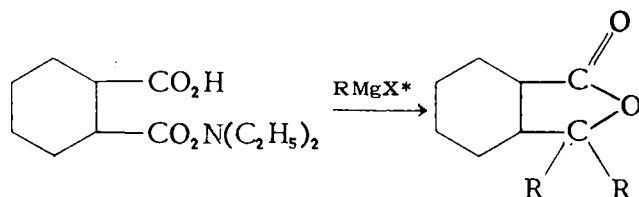
An unusual case of reductive anil formation has been reported by Skraup and Moser.¹⁶



Such a reaction appears all the more remarkable in that it is not conducted under "forced" conditions. It would probably repay further study, with due attention to the exclusion of excess magnesium.

PHTHALIDE FORMATION

Maxim and Andreescu¹⁷ report the formation of 3,3-disubstituted phthalides by the action of Grignard reagents on *N,N*-diethylphthalamic acid.



α -HALO AMIDES

In so far as they have been studied, the reactions of the α -halo amides appear to have something in common with those of the α -halo ketones (*q.v.*). Sou Phou Ti¹⁸ has reported the products of the reaction of excess phenylmagnesium bromide with α -bromo-*N,N*-diethylbutyramide as *N,N*-diethylbutyramide, *N,N*-diethylcrotonamide, *n*-propyldiphenylcarbinol, and butyrophenone (trace). He attributes dehalogenation to the action of excess magnesium, which is assumed to form a Grignard reagent that

¹⁵Montagne and Rousseau, *Compt. rend.*, 196, 1165-7 (1933).

¹⁶Skraup and Moser, *Ber.*, 55B, 1080-101 (1922).

¹⁷Maxim and Andreescu, *Bull. soc. chim.*, [5], 5, 54-7 (1938).

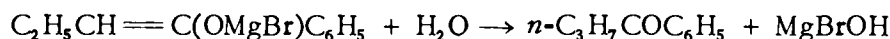
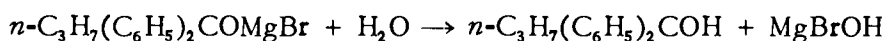
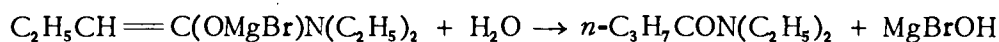
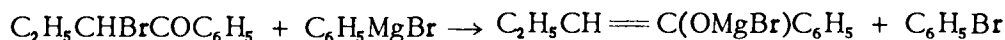
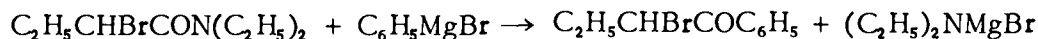
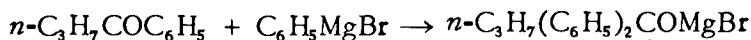
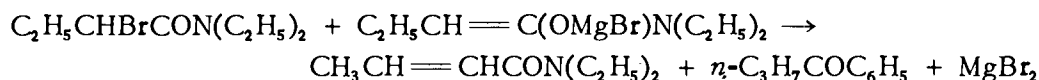
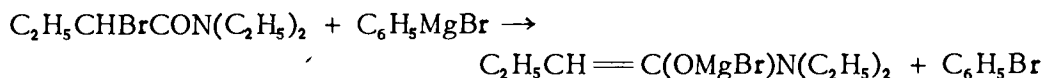
*RMgX = *n*-C₃H₇MgBr, *i*-C₄H₉MgCl, *i*-C₅H₁₁MgBr, C₆H₅MgBr, C₆H₅CH₂MgCl.

¹⁸Sou Phou Ti, *Bull. soc. chim.*, [5], 2, 1799-800 (1935). See also: *Chem. Abstr.*, 29, 2519 (1935).

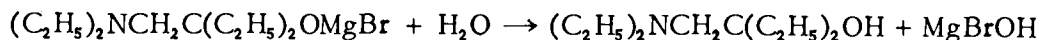
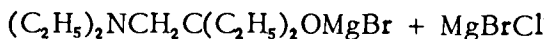
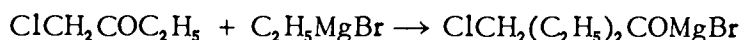
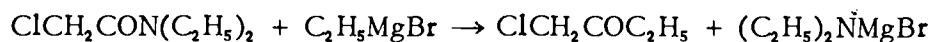
then reacts further with phenylmagnesium bromide. The crotonamide is supposed to result in some manner not fully explained from the combined action of water and excess magnesium on residual α -bromobutyramide.

It is unfortunate that an unnecessary complication was introduced into this study by failure to take precautions against the presence of excess magnesium. The work should be repeated with magnesium-free reagent prepared from sublimed magnesium.

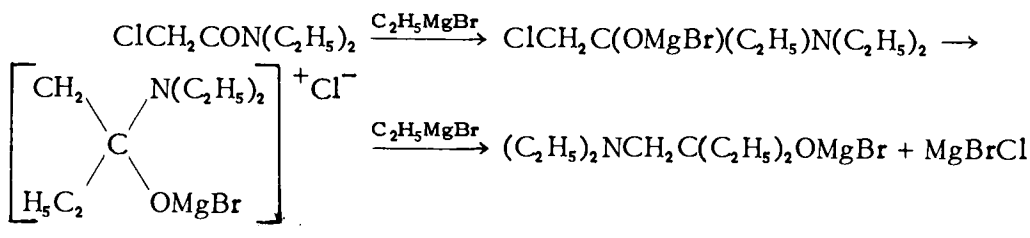
If the reaction products found in the absence of metallic magnesium were the same as those reported by Sou Phou Ti (with the addition of bromobenzene) a reasonably plausible explanation might be constructed on the basis of analogy with the known behavior of α -halo ketones, *q.v.*



The same investigator¹⁹ has reported the formation of an amino alcohol by the action of ethylmagnesium bromide on *N,N*-diethylchloroacetamide. The product isolated might well arise from the following reaction sequence.



If it be assumed that addition at the carbonyl double bond is a step in the "normal" cleavage reaction another possible reaction sequence suggests itself.

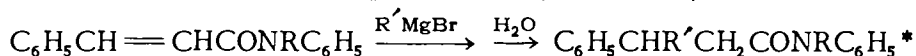


¹⁹Sou Phou Ti, *Compt. rend.*, 192, 1462-4 (1931).

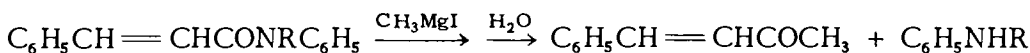
Neither of the sequences suggested should be interpreted as implying anything concerning mechanistic detail, nor should it be inferred that still other probable sequences are inconceivable. The sole object of these speculations is to show that a product which at first glance appears unusual may be the result of reactions of well-known types.

α,β -UNSATURATED AMIDES

In an investigation of the reactions of Grignard reagents with α,β -unsaturated compounds, Kohler and Heritage²⁰ found that phenylmagnesium bromide reacts with *N*-ethylcinnamamide by 1,4-addition. Having apparently overlooked this work, Maxim and Ioanid²¹ repeated and extended it, obtaining nearly quantitative yields of 1,4-addition products.



The reaction of methylmagnesium iodide was exceptional in that, under comparable conditions (four hours reflux in ether; twelve hours standing), considerable amounts of amide remained unchanged, the rest being converted to unsaturated methyl ketone and amine.



Similar 1,4-additions to *N,N*-disubstituted cinnamamides, crotonamides, and furfurylideneacetamides have been reported by Maxim *et al.*²² Other examples are included in Table XII-I.

AMIDE CONDENSATIONS

From the reaction of methylmagnesium iodide with *N*-phenylcrotonamide Maxim²³ was able to isolate only about 1-2 percent of the 1,4-addition product, but obtained in about 80 percent yield a condensation product of empirical formula $\text{C}_{33}\text{H}_{34}\text{N}_2\text{O}_2$ to which he assigned the constitution $(\text{C}_6\text{H}_5)_2\text{NCH}(\text{CH}_3)\text{CH}[\text{CON}(\text{C}_6\text{H}_5)_2]\text{CO}-i\text{-C}_4\text{H}_9$. Nenitzescu²⁴ has repeated this work and declares that the product is actually $(\text{C}_6\text{H}_5)_2\text{NCOCH}_2\text{CH}(\text{CH}_3)\text{CH}[\text{CON}(\text{C}_6\text{H}_5)_2]-i\text{-C}_3\text{H}_7$, *i.e.*, the one which would be expected to result from 1,4-condensation of the enolate (formed by

²⁰Kohler and Heritage, *Am. Chem. J.*, 33, 21-35 (1905).

²¹Maxim and Ioanid, *Bull. soc. chim. România*, 10, 29-48 (1928); *Chem. Zentr.*, 1928,III, 754; *Chem. Abstr.*, 22, 4114 (1928).

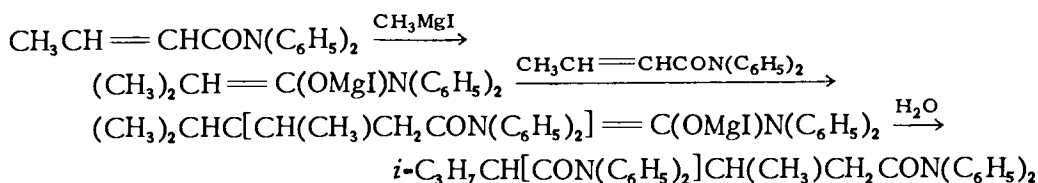
*R = CH₃, C₂H₅, C₆H₅; R' = C₂H₅, C₆H₅.

²²(a) Maxim, *Ann. chim.*, [10], 9, 55-111 (1928); (b) Maxim, *Bull. soc. chim. România*, 10, 97-115 (1928); *Chem. Zentr.*, 1929,I, 2161; *Chem. Abstr.*, 23, 2697 (1929); (c) Maxim and Ioanid, *Bull. soc. chim. România*, 12, 28-32 (1930); *Chem. Zentr.*, 1930,II, 3013; *Chem. Abstr.*, 25, 488 (1931); (d) Maxim and Zugravescu, *Bull. soc. chim.*, [5], 1, 1987-99 (1934); (e) Maxim and Stancovici, *ibid.*, [5], 3, 1319-23 (1936).

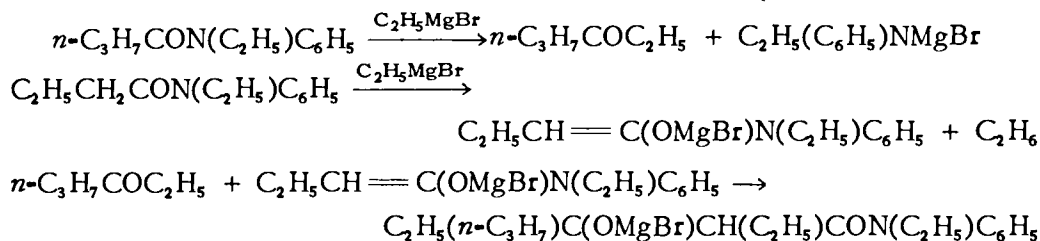
²³Maxim, *Bull. soc. chim. România*, 11, 123-9 (1929); *Chem. Zentr.*, 1930,I, 2550; *Chem. Abstr.*, 24, 2427 (1930).

²⁴Nenitzescu, *Bull. soc. chim. România*, 12, 48-57 (1930); *Chem. Zentr.*, 1930,II, 3014; *Chem. Abstr.*, 25, 1509 (1931).

1,4-addition of the Grignard reagent to the amide) with a second molecule of amide.



A somewhat different type of condensation has been reported by Montagne and Isambert²⁵ as resulting from the reaction of *N*-ethylbutyranilide with ethylmagnesium bromide. Apparently a part of the amide reacts "normally", forming 3-hexanone, whereas a part "enolizes". Condensation between ketone and enolate then takes place.



UNREACTIVE AMIDES

Some amides that have been reported as unreactive toward Grignard reagents in ethereal solution are as follows: (—CONH₂)₂, C₆H₅CON(C₂H₅)₂ (McKenzie and Duff²⁶); C₆H₅CON(C₂H₅)₂, C₆H₄-1,2-[CON(C₂H₅)₂]₂, C₂H₅(C₆H₅)CHCH₂CON(C₂H₅)₂, (C₆H₅)₂CHCON(C₂H₅)₂, (C₆H₅)₂CHCH₂CON(C₂H₅)₂, (C₆H₅CH₂)₂CHCON(C₂H₅)₂ (Maxim²⁷); (C₆H₅)₂C(OH)CONH₂ (Burton²⁸); DL-C₆H₅CH(OH)CONHC₂H₅ (McKenzie *et al.*²⁹); 3,4-(HO)₂-C₆H₃CON(C₂H₅)₂, 3,4,5-(HO)₃C₆H₂CON(C₂H₅)₂ (Couturier³⁰); HCONHNHC₆H₅, CH₃CONHNHC₆H₅, C₆H₅CONHNHC₆H₅ (Grammaticakis³¹). In some cases at least the apparent lack of reactivity is probably due to initial reaction of the amide as an "active hydrogen" compound, with the formation of a relatively insoluble halomagnesium derivative.

IMIDES

The published data on the reactions of Grignard reagents with imides are very meagre. Béřis³² reported the formation of isoindolones from phthalimide. The reactions probably take the following course.

²⁵Montagne and Isambert, *Compt. rend.*, 208, 285-7 (1939); *Chem. Abstr.*, 33, 3772 (1939).

²⁶McKenzie and Duff, *Ber.*, 60B, 1335-41 (1927).

²⁷Maxim, *Compt. rend.*, 182, 1393-5 (1926); *Ann. chim.*, [10], 9, 55-111 (1928).

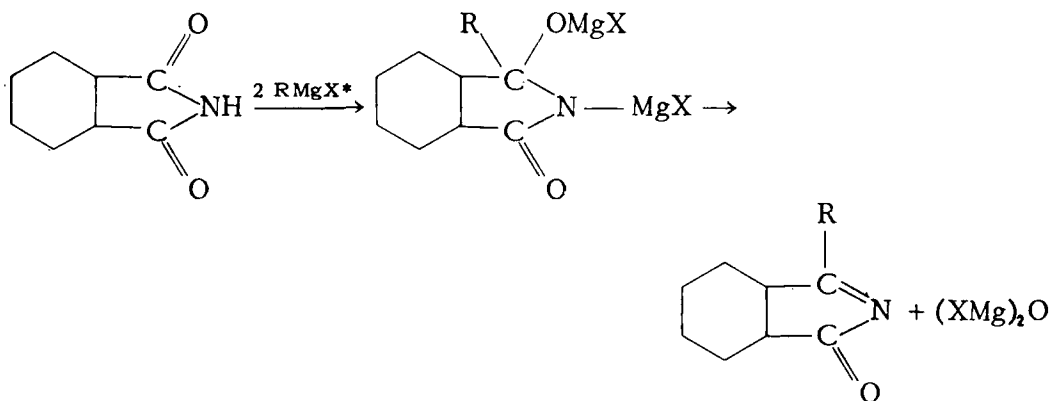
²⁸Burton, *J. Chem. Soc.*, 1930, 2400.

²⁹McKenzie, Martin, and Rule, *J. Chem. Soc.*, 105, 1583-91 (1914).

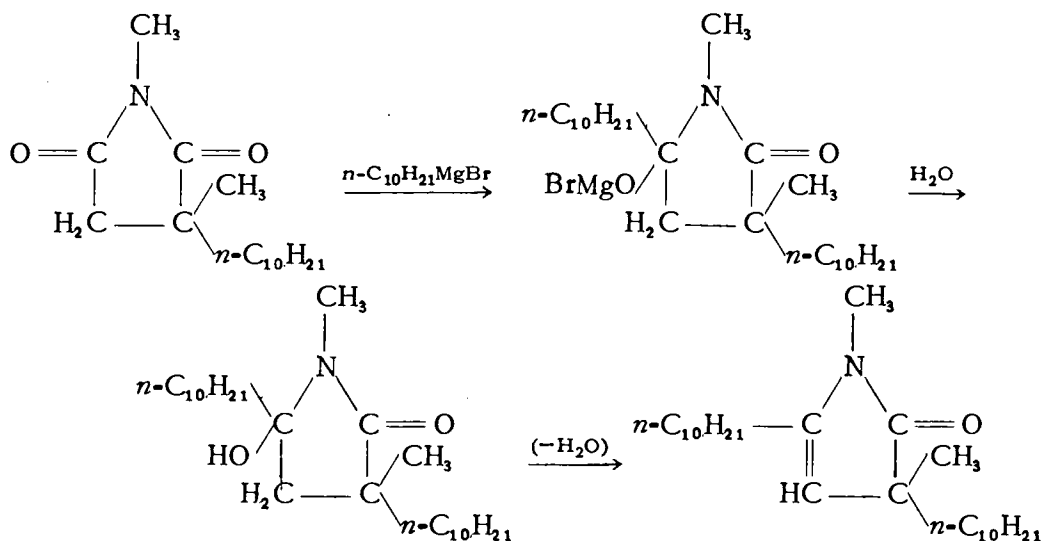
³⁰Couturier, *Ann. chim.*, [11], 10, 559-629 (1938).

³¹Grammaticakis, *Compt. rend.*, 207, 239-41 (1938); *Chem. Abstr.*, 34, 2808 (1940).

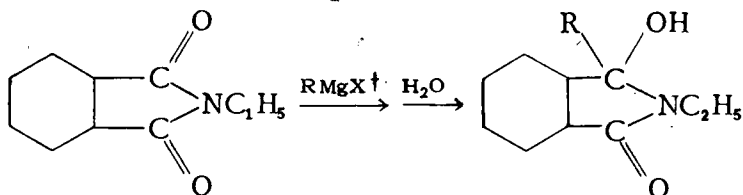
³²Béřis, *Compt. rend.*, 138, 987-9 (1904); *Chem. Zentr.*, 1904,1, 1446.



The reaction of *N*, α -dimethyl- α -*n*-decylsuccinimide with *n*-decylmagnesium bromide, according to Birch and Robinson³³, also involves a dehydration, but one of a different type, which probably follows a different course.



According to Sachs and Ludwig,³⁴ *N*-ethylphthalimide reacts with Grignard reagents to form substituted phthalimidines in "good yields".



Reactions of the same type are reported for *N*-methylsuccinimide (Lukeš *et al.*³⁵) and *N*-methylglutarimide (Lukeš and Gorochohinskij³⁶).

* $\text{R} = \text{C}_2\text{H}_5$, *i*-C₄H₉, *i*-C₅H₁₁.

³³Birch and Robinson, *J. Chem. Soc.*, 1942, 488-97.

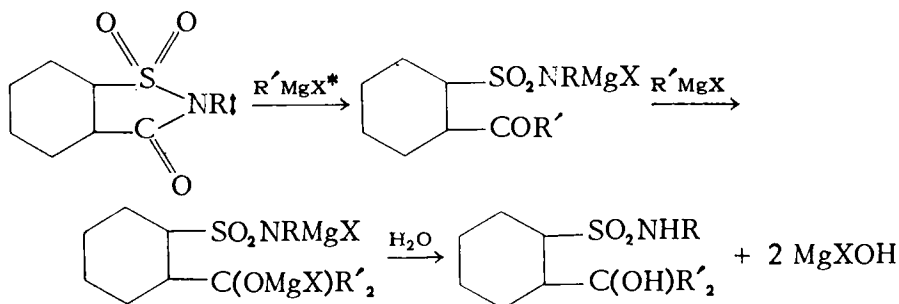
³⁴Sachs and Ludwig, *Ber.*, 37, 385-90 (1904).

[†] $\text{R} = \text{CH}_3$, C₂H₅, C₆H₅.

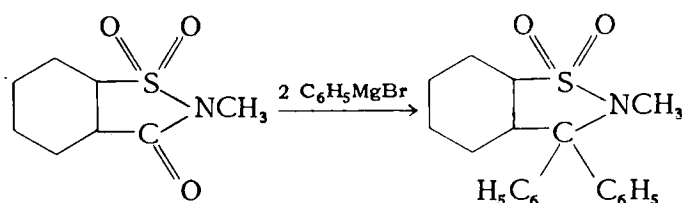
³⁵Lukeš and Prelog, *Chem. Listy*, 22, 244-51 (1928); *Chem. Abstr.*, 23, 1408 (1929); Lukeš, *Collection Czechoslov. Chem. Commun.*, 5, 761-9 (1932); *Chem. Abstr.*, 27, 290 (1933); Lukeš and Smolek, *Collection Czechoslov. Chem. Commun.*, 7, 482-90 (1935); *Chem. Abstr.*, 30, 1785 (1936).

³⁶Lukeš and Gorochohinskij, *Collection Czechoslov. Chem. Commun.*, 8, 223-35 (1936); *Chem. Abstr.*, 30, 5989 (1936).

N-Alkylated saccharins have been reported to undergo ring-opening (Sachs and Ludwig, *loc. cit.*³⁴; Sachs *et al.*³⁷).

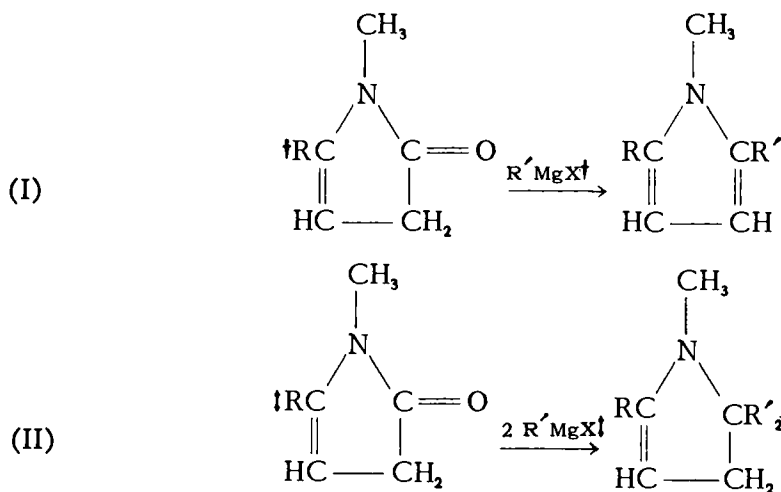


Cobb and Fuller,³⁸ however, report a cyclic product of the reaction of phenylmagnesium bromide with *N*-methylsaccharin.



LACTAMS

Lukeš³⁹ has reported on the reactions of several 1-methyl-5-alkyl-2(3*H*)-pyrrolones with various Grignard reagents. The following types of reactions are said to occur.



³⁷Sachs, Wolff, and Ludwig, *Ber.*, 37, 3252-68 (1904).

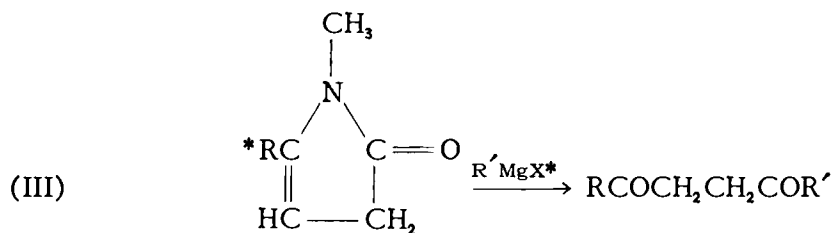
*R = CH₃, C₂H₅; R' = CH₃, C₂H₅, *i*-C₃H₇, *i*-C₅H₁₁, C₆H₅.

³⁸Cobb and Fuller, *Am. Chem. J.*, 45, 605-11 (1911).

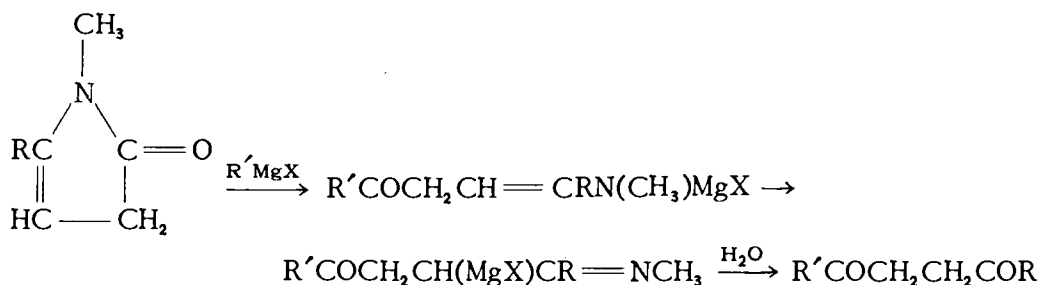
³⁹Lukeš, *Collection Czechoslov. Chem. Commun.*, 4, 181-92 (1932); *Chem. Zentr.*, 1932, II, 873; *Chem. Abstr.*, 26, 4328 (1932).

†R = CH₃, R'MgX = CH₃MgBr; R = C₂H₅, R'MgX = CH₃MgBr, C₂H₅MgBr, C₆H₅CH₂MgCl; R = C₆H₅CH₂, R'MgX = CH₃MgBr, C₂H₅MgBr, C₆H₅CH₂MgCl.

‡R = C₂H₅, R'MgX = C₂H₅MgBr; R = C₆H₅CH₂, R'MgX = CH₃MgBr.



Reaction of type I consists (formally, at least) of "normal" addition at the carbonyl double bond followed by either elimination of halomagnesium hydroxide prior to hydrolysis or elimination of water subsequent to hydrolysis. Reaction of type II resembles amine formation from an acyclic amide and may well take the same course. Conceivably, however, it could consist in alkylation of a cyclic amine formed by elimination of halomagnesium hydroxide from the initial addition product. Reaction of type III might take place through some such sequence as the following.



Aside from the secondary rearrangement this is essentially "normal" ketone formation from an *N,N*-disubstituted amide. These three reaction types include all that have been reported for simple lactams and α -amino acid hydrides. Other examples are included in Table XII-I.

*R = C₂H₅; R'MgX = C₂H₅MgBr, C₆H₅CH₂MgCl.

TABLE XII-I
REACTIONS OF GRIGNARD REAGENTS WITH AMIDES, IMIDES, AND LACTAMS

Co-reactant	RMgX	Product(s)	Ref.
CHO-NRR'			
HCONH ₂	RMgX	"Does not react like other amides"	2
HCON(CH ₃) ₂	<i>i</i> -C ₄ H ₉ MgCl	<i>i</i> -C ₄ H ₉ CHO	7
HCON(CH ₃) ₂ (20 g.)	<i>i</i> -C ₄ H ₉ MgCl (83 g. C ₄ H ₉ Cl)	<i>i</i> -C ₄ H ₉ CHO (13.0 g., 56%); (<i>i</i> -C ₄ H ₉) ₂ CHN(CH ₃) ₂ (15 g.)	53
HCON(CH ₃) ₂	<i>t</i> -C ₄ H ₉ MgCl	<i>t</i> -C ₄ H ₉ CHO ("insignificant quantity")	7
HCON(CH ₃) ₂	<i>i</i> -C ₅ H ₁₁ MgCl	<i>i</i> -C ₅ H ₁₁ CHO; (<i>i</i> -C ₅ H ₁₁) ₂ CHN(C ₂ H ₅) ₂	7,6
HCON(CH ₃) ₂ (20 g.)	<i>i</i> -C ₅ H ₁₁ MgBr (130 g. C ₅ H ₁₁ Br)	Recovered amide (5 g.); <i>i</i> -C ₅ H ₁₁ CHO (11 g., 40%); (<i>i</i> -C ₅ H ₁₁) ₂ CHN(CH ₃) ₂ (20 g.)	53
HCON(CH ₃) ₂	<i>t</i> -C ₅ H ₁₁ MgCl	<i>t</i> -C ₅ H ₁₁ CHO ("few drops")	7
HCON(CH ₃) ₂ (30 g.)	C ₆ H ₅ MgBr (140 g. C ₆ H ₅ Br)	C ₆ H ₅ CHO (15 g., 34%); (C ₆ H ₅) ₂ CHOH (12 g., 16%); (C ₆ H ₅) ₂ CHN(CH ₃) ₂ (10 g.)	53,7
HCON(CH ₃) ₂	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CHCHO ("good yield")	7
HCON(CH ₃) ₂	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ CHO ("good yield")	7
HCON(CH ₃) ₂	<i>n</i> -C ₈ H ₁₇ MgCl	<i>n</i> -C ₈ H ₁₇ CHO	7
HCON(CH ₃) ₂	<i>n</i> -C ₉ H ₁₉ MgCl	<i>n</i> -C ₉ H ₁₉ CHO	7
HCON(C ₂ H ₅) ₂ (50 g.)	C ₂ H ₅ MgBr (120 g. C ₂ H ₅ Br)	Recovered amide; (C ₂ H ₅) ₂ CHN(C ₂ H ₅) ₂ (20 g., 22%)*	44
HCON(C ₂ H ₅) ₂ (35 g.)	C ₂ H ₅ MgBr (120 g. C ₂ H ₅ Br)	(C ₂ H ₅) ₂ CHN(C ₂ H ₅) ₂ (25 g., 51%) [†]	44
HCON(C ₂ H ₅) ₂ (30 g.)	C ₂ H ₅ MgI (146 g. C ₂ H ₅ I)	(C ₂ H ₅) ₂ CHN(C ₂ H ₅) ₂ (17 g., 41%)	44
HCON(C ₂ H ₅) ₂	CH ₃ C≡CMgBr	(CH ₃ C≡C) ₂ CHN(C ₂ H ₅) ₂	86
HCON(C ₂ H ₅) ₂ (30 g.)	<i>n</i> -C ₃ H ₇ MgBr (37 g. C ₃ H ₇ Br)	<i>n</i> -C ₃ H ₇ CHO (6 g.); (<i>n</i> -C ₃ H ₇) ₂ CHN(C ₂ H ₅) ₂ (9 g.)	52
HCON(C ₂ H ₅) ₂ (50 g.)	<i>n</i> -C ₃ H ₇ MgBr (180 g. C ₃ H ₇ Br)	(<i>n</i> -C ₃ H ₇) ₂ CHN(C ₂ H ₅) ₂ (30 g.)	52

*Dropwise addition of Et₂O-amide solution to cooled Et₂O-Grignard reagent solution; twelve hours standing.

[†]Addition of C₆H₆-amide solution to C₆H₆-Grignard reagent solution.

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CHO-NRR' (cont.)			
HCON(C ₂ H ₅) ₂ (40 g.)	<i>i</i> -C ₄ H ₉ MgBr (69 g. C ₄ H ₉ Br)	Recovered amide; <i>i</i> -C ₄ H ₉ CHO (8 g., 23%); (<i>i</i> -C ₄ H ₉) ₂ CHN(C ₂ H ₅) ₂ (ca. 17%)	44
HCON(C ₂ H ₅) ₂ (40 g.)	<i>i</i> -C ₄ H ₉ MgBr (140 g. C ₄ H ₉ Br)	<i>i</i> -C ₄ H ₉ CHO (10 g., 29%); (<i>i</i> -C ₄ H ₉) ₂ CHN(C ₂ H ₅) ₂ (17 g., 22%)	44
HCON(C ₂ H ₅) ₂ (40 g.)	C ₆ H ₅ MgBr (140 g. C ₆ H ₅ Br)	C ₆ H ₅ CHO (25 g., 60%); (C ₆ H ₅) ₂ CHOH (10 g., 13%); [(C ₆ H ₅) ₂ C=] ₂ (12 g., 18%)	53
HCON(C ₂ H ₅) ₂	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ CHO ("good yield")	7
HCON(CH ₂) ₅ (40 g.)	C ₂ H ₅ MgBr (55 g. C ₂ H ₅ Br)	Recovered amide (7 g.); (C ₂ H ₅) ₂ CHN(CH ₂) ₅ (16 g.); (CH ₂) ₅ N (5 g.)	52
HCON(CH ₂) ₅ (40 g.)	C ₂ H ₅ MgBr (116 g. C ₂ H ₅ Br)	(C ₂ H ₅) ₂ CHN(CH ₂) ₅ (32 g.); (CH ₂) ₅ NH (3 g.); C ₂ H ₅ CHO (trace)	52
HCON(CH ₂) ₅ (30 g.)	<i>n</i> -C ₃ H ₇ MgBr (71 g. C ₃ H ₇ Br)	<i>n</i> -C ₃ H ₇ CHO (5 g.); (<i>n</i> -C ₃ H ₇) ₂ CHN(CH ₂) ₅ (31 g.)	53
HCON(CH ₂) ₅ (30 g.)	<i>i</i> -C ₄ H ₉ MgCl (80 g. C ₄ H ₉ Cl)	<i>i</i> -C ₄ H ₉ CHO (4 g.); (<i>i</i> -C ₄ H ₉) ₂ CHN(CH ₂) ₂ (42 g.)	53,6
HCON(CH ₂) ₅ (20 g.)	C ₆ H ₅ MgBr (88 g. C ₆ H ₅ Br)	[(C ₆ H ₅) ₂ C=] ₂ (22 g.); C ₆ H ₅ CHO (2 g., 11%) (C ₆ H ₅) ₂ CHN(CH ₂) ₅ (27 g.)	53
HCON(CH ₂) ₅ (30 g.)	C ₆ H ₅ CH ₂ MgCl (74 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CHO (10 g.); (C ₆ H ₅ CH ₂) ₂ CHN(CH ₂) ₅ (8 g.)	53
HCONHNHC ₆ H ₅	C ₆ H ₅ MgBr ("large excess")	(C ₆ H ₅) ₂ CO (chiefly); (C ₆ H ₅) ₂ C=NNHC ₆ H ₅ ("very little"); (C ₆ H ₅) ₂ C=NC ₆ H ₅ ("very little")*	20
HCON(CH ₃)C ₆ H ₅ (50 g.)	C ₂ H ₅ MgBr (133 g. C ₂ H ₅ Br)	(C ₂ H ₅) ₂ CHN(CH ₃)C ₆ H ₅ (> 20 g.); CH ₃ NHC ₆ H ₅	52
HCON(CH ₃)C ₆ H ₅ (30 g.)	<i>i</i> -C ₄ H ₉ MgCl (25 g. C ₄ H ₉ Cl)	Recovered amide (10 g.); <i>i</i> -C ₄ H ₉ CHO (6 g.); (<i>i</i> -C ₄ H ₉) ₂ CHN(CH ₃)C ₆ H ₅ (1-2 g.); CH ₃ NHC ₆ H ₅	52

*Reaction at 116-120°, seven to twelve hours.

TABLE XII-I (Continued)

Co-reactant	RMgX	Product(s)	Ref.
CHO-NRR' (cont.)			
HCON(CH ₃)C ₆ H ₅ (45 g.)	<i>i</i> -C ₄ H ₉ MgCl (90 g. C ₄ H ₉ Cl)	<i>i</i> -C ₄ H ₉ CHO (10 g.); (<i>i</i> -C ₄ H ₉) ₂ CHN(CH ₃)C ₆ H ₅ (20 g.); CH ₃ NHC ₆ H ₅	52
HCON(CH ₃)C ₆ H ₅ (20 g.)	C ₆ H ₅ MgBr (70 g. C ₆ H ₅ Br)	C ₆ H ₅ CHO (10 g., 64%); (C ₆ H ₅) ₂ CHOH (10 g., 35%); CH ₃ NHC ₆ H ₅ (14 g.)	53
HCON(CH ₃)C ₆ H ₅ (0.2 mole)	C ₆ H ₅ MgBr (0.2 mole C ₆ H ₅ Br)	C ₆ H ₅ CHO (59%); C ₆ H ₅ NHCH ₃ *	75
HCON(CH ₃)C ₆ H ₅ (0.2 mole)	C ₆ H ₅ MgBr (0.2 mole C ₆ H ₅ Br)	C ₆ H ₅ CHO (11%); C ₆ H ₅ NHCH ₃ †	75
HCON(CH ₃)C ₆ H ₅ (0.37 mole)	C ₆ H ₅ MgBr (0.2 mole C ₆ H ₅ Br)	C ₆ H ₅ CHO (67%); C ₆ H ₅ NHCH ₃ ‡	75
HCON(CH ₃)C ₆ H ₅ (0.37 mole)	C ₆ H ₅ MgBr (0.2 mole C ₆ H ₅ Br)	C ₆ H ₅ CHO (67%); C ₆ H ₅ NHCH ₃ §	75
HCON(CH ₃)C ₆ H ₅ (100% excess)	2-CH ₃ C ₆ H ₄ MgBr (0.2 mole C ₆ H ₅ Br)	2-CH ₃ C ₆ H ₄ CHO (11 g., 50%); C ₆ H ₅ NHCH ₃	75
HCON(CH ₃)C ₆ H ₅ (25% excess)	3-CH ₃ C ₆ H ₄ MgBr (0.2 mole C ₇ H ₇ Br)	3-CH ₃ C ₆ H ₄ CHO (8 g., 33%); C ₆ H ₅ NHCH ₃	75
HCON(CH ₃)C ₆ H ₅	4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ CHO (9 g., 37%)	75
HCON(CH ₃)C ₆ H ₅	2,5-(CH ₃ O) ₂ C ₆ H ₃ MgBr	2,5-(CH ₃ O) ₂ C ₆ H ₃ CHO (17-22%); C ₆ H ₅ NHCH ₃ ; 1,4-(CH ₃ O) ₂ C ₆ H ₄ (38%)	75
HCON(CH ₃)C ₆ H ₅	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CHO (18.8%); C ₆ H ₅ NHCH ₃ ; 2,4,6-(CH ₃) ₃ C ₆ H ₃ (40%)	75
HCON(CH ₃)C ₆ H ₅ (1 equiv.)	C ₁₀ H ₁₇ MgCl¶	CH ₃ (C ₆ H ₅)N(C ₁₀ H ₁₇)CHOH (yielding 23-24 g. aldehyde-bisulfite compound)	22
HCON(CH ₃)C ₆ H ₅ (13.5 g.)	2-C ₆ H ₅ C ₆ H ₄ MgI (28 g. C ₁₂ H ₉ I)	2-C ₆ H ₅ C ₆ H ₄ CHO (12.2 g.)	85
HCON(C ₂ H ₅)C ₆ H ₅ (50 g.)	C ₂ H ₅ MgBr (115 g. C ₂ H ₅ Br)	(C ₂ H ₅) ₂ CHN(C ₂ H ₅)C ₆ H ₅ (26 g.)	52
HCON(C ₂ H ₅)C ₆ H ₅ (30 g.)	<i>i</i> -C ₄ H ₉ MgCl (22 g. C ₄ H ₉ Cl)	Recovered amide (12 g.); <i>i</i> -C ₄ H ₉ CHO (6 g.); (<i>i</i> -C ₄ H ₉) ₂ CHN(C ₂ H ₅)C ₆ H ₅ (1-2 g.); C ₂ H ₅ NHC ₆ H ₅ (14 g.)	52

*Slow addition of amide to stirred Grignard reagent solution; overnight standing.

†Replacement of Et₂O by CH₃C₆H₅; heating at 90°.

‡Normal addition.

§Reverse addition.

¶From 50 g. of pinene hydrochloride.

TABLE XII-I (Continued)

Co-reactant	RMgX	Product(s)	Ref.
CHO-NRR' (cont.)			
HCON(C ₂ H ₅)C ₆ H ₅ (46 g.)	<i>i</i> -C ₄ H ₉ MgCl (83 g. C ₄ H ₉ Cl)	<i>i</i> -C ₄ H ₉ CHO (6 g.); (<i>i</i> -C ₄ H ₉) ₂ CHN(C ₂ H ₅)C ₆ H ₅ (30 g.); C ₂ H ₅ NHC ₆ H ₅ (5 g.)	52
HCON(C ₂ H ₅)C ₆ H ₅	C ₆ H ₅ MgBr	C ₆ H ₅ CHO	6
HCON(C ₂ H ₅)C ₆ H ₅	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CHCHO	6
HCON(C ₂ H ₅)C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ CHO	6
HCON(C ₆ H ₅) ₂ (30 g.)	C ₂ H ₅ MgBr (55 g. C ₂ H ₅ Br)	(C ₆ H ₅) ₂ NH (17 g.); (C ₂ H ₅) ₂ CHN(C ₆ H ₅) ₂ (8 g.)	53
HCON(C ₆ H ₅) ₂ (30 g.)	<i>i</i> -C ₄ H ₉ MgCl (51 g. C ₄ H ₉ Cl)	<i>i</i> -C ₄ H ₉ CHO (5 g.); (<i>i</i> -C ₄ H ₉) ₂ CHN(C ₆ H ₅) ₂ (12 g.); (C ₆ H ₅) ₂ NH	52
HCON(C ₆ H ₅) ₂ (20 g.)	C ₆ H ₅ MgBr (50 g. C ₆ H ₅ Br)	C ₆ H ₅ CHO (1 g.); (C ₆ H ₅) ₂ CHOH (16 g., 88%)	53
C₂O₂-(NRR')₂			
(—CONH ₂) ₂ (8 g.)	C ₆ H ₅ MgBr (86 g. C ₆ H ₅ Br)	Recovered amide (7.5 g.)	57
[—CON(C ₂ H ₅) ₂] ₂	C ₂ H ₅ MgBr (3 equiv.)	C ₂ H ₅ COCON(C ₂ H ₅) ₂ (70%); (C ₂ H ₅) ₂ NCH(C ₂ H ₅)CON(C ₂ H ₅) ₂ (20%); (C ₂ H ₅ CO—) ₂ (trace); C ₂ H ₄ [*]	1
[—CON(C ₂ H ₅) ₂] ₂	C ₂ H ₅ MgBr (3 equiv.)	C ₂ H ₅ COCON(C ₂ H ₅) ₂ (55%); (C ₂ H ₅) ₂ NCH(C ₂ H ₅)CON(C ₂ H ₅) ₂ (36%); (C ₂ H ₅ CO—) ₂ (1%); C ₂ H ₄ [†]	1
[—CON(C ₂ H ₅) ₂] ₂	C ₂ H ₅ MgBr (4 equiv.)	C ₂ H ₅ COCON(C ₂ H ₅) ₂ (28%); (C ₂ H ₅) ₂ NCH(C ₂ H ₅)CON(C ₂ H ₅) ₂ (60%); (C ₂ H ₅ CO—) ₂ (3%); C ₂ H ₄ [‡]	1
[—CON(C ₂ H ₅) ₂] ₂	C ₂ H ₅ Mgl (3 equiv.)	C ₂ H ₅ COCON(C ₂ H ₅) ₂ (80%); (C ₂ H ₅) ₂ NCH(C ₂ H ₅)CON(C ₂ H ₅) ₂ (very little); C ₂ H ₄ [†]	1

* Four hours reflux in Et₂O.† Ten hours at 70° in C₆H₆.‡ Two hours agitation at 90° in CH₃C₆H₅ under H₂.

TABLE XII-I (Continued)

Co-reactant	RMgX	Product(s)	Ref.
C₂O₂-(NRR')₂ (cont.)			
[—CON(C ₂ H ₅) ₂] ₂	C ₆ H ₅ MgBr (4 equiv.)	(C ₂ H ₅) ₂ NC(C ₆ H ₅) ₂ CON(C ₂ H ₅) ₂ (75%)*	1
<i>N,N'</i> -Vinylideneoxanilide	RMgX† (2+ equiv.)	(RCO—) ₂	80
[—CON(CH ₃)C ₆ H ₅] ₂ (1 mole)	CH ₃ MgI (4 moles)	CH ₃ (C ₆ H ₅)NCOCOCH ₃	88
[—CON(CH ₃)C ₆ H ₅] ₂ (1 mole)	C ₂ H ₅ MgBr (4 moles)	CH ₃ (C ₆ H ₅)NCOCOC ₂ H ₅ (27 g., crude)	88
[—CON(CH ₃)C ₆ H ₅] ₂	4-CH ₃ C ₆ H ₄ MgBr (4 equiv.)	CH ₃ (C ₆ H ₅)NCOCOC ₆ H ₄ -4-CH ₃	88
C₂H₂OCl-NRR'			
ClCH ₂ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	(C ₂ H ₅) ₂ NCH ₂ (C ₂ H ₅) ₂ COH	76
C₂H₃O-NRR'			
CH ₃ CONH ₂	CH ₃ MgI (2+ equiv.)	(CH ₃) ₂ CO (poor yield)	2
CH ₃ CONH ₂	C ₂ H ₅ MgX† (2+ equiv.)	CH ₃ COC ₂ H ₅ (poor yield)	2
CH ₃ CONH ₂	Pyrryl-MgBr	<i>α</i> -Amino- <i>α</i> -2-pyrrolethanol	72
CH ₃ CONH ₂	C ₆ H ₅ CH ₂ MgCl (3 equiv.)	CH ₃ COCH ₂ C ₆ H ₅ (41.3%)	82
CH ₃ CONH ₂ (20 g., 0.33 mole)	<i>n</i> -C ₅ H ₁₁ C≡CMgBr (96 g. C ₇ H ₁₂)	<i>n</i> -C ₅ H ₁₁ C≡CH (90 g.)	33
CH ₃ CONHC ₆ H ₅	C ₂ H ₅ MgBr (excess)	Butanone condens'n products and recovered amide, only	63
CH ₃ CONHNHC ₆ H ₅	C ₆ H ₅ MgBr	2-Phenylindole (chiefly); CH ₃ (C ₆ H ₅)C=NNHC ₆ H ₅ ("a little"); CH ₃ COC ₆ H ₅ ("a little")§	20
C₃H₅O-NRR'			
C ₂ H ₅ CONH ₂	CH ₃ MgI (2+ equiv.)	CH ₃ COC ₂ H ₅ (ca. 20%)	2

* One and one-half hour reflux in CH₃C₆H₅ under H₂.† RMgX = CH₃MgI, C₂H₅MgBr.

‡ X = Br, I.

§ Reaction at 116–120°, 7–12 hrs.

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₅O-NRR' (<i>cont.</i>)			
C ₂ H ₅ CONH ₂	C ₂ H ₅ MgX* (2+ equiv.)	(C ₂ H ₅) ₂ CO (<i>ca.</i> 20%)	2
C ₂ H ₅ CONHC ₆ H ₅	C ₂ H ₅ MgBr (excess)	(C ₂ H ₅) ₂ C=NC ₆ H ₅ (<i>ca.</i> 40%); unsat'd ketone, C ₁₀ H ₁₈ O, b. 90-93°/20 mm.; recovered amide	63
C₄H₄O₂-NR			
N-Methylsuccinimide	RMgX†	1-Methyl-5-hydroxy-5-R-2-pyrrolidone	37
N-Methylsuccinimide	C ₆ H ₅ MgBr	1-Methyl-5-hydroxy-5-phenyl-2-pyrrolidone; 1-methyl-2,5-diphenylpyrrole	39,40
C₄H₄O₂-(NRR')₂			
[—CH ₂ CON(C ₂ H ₅) ₂] ₂	C ₂ H ₅ MgBr	C ₂ H ₅ COCH ₂ CH ₂ CON(C ₂ H ₅) ₂ (63%); (—CH ₂ COC ₂ H ₅) ₂ (3%)	63
C₄H₅O-NRR'			
CH ₃ CH=CHCON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)CHCH ₂ CON(C ₂ H ₅) ₂ (quant.)	46
CH ₃ CH=CHCON(C ₂ H ₅) ₂	C ₆ H ₅ MgBr	CH ₃ (C ₆ H ₅)CHCH ₂ CON(C ₂ H ₅) ₂ (quant.)	46
CH ₃ CH=CHCON(CH ₃)C ₆ H ₅	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)CHCH ₂ CON(CH ₃)C ₆ H ₅ (40-50%)	51
CH ₃ CH=CHCON(CH ₃)C ₆ H ₅	C ₆ H ₅ MgBr	CH ₃ (C ₆ H ₅)CHCH ₂ CON(CH ₃)C ₆ H ₅ (40-50%); (C ₆ H ₅ —) ₂ ; unidentified product	51
CH ₃ CH=CHCON(C ₂ H ₅)C ₆ H ₅	C ₂ H ₅ MgBr‡	CH ₃ (C ₂ H ₅)CHCH ₂ CON(C ₂ H ₅)C ₆ H ₅ (40-50%)	51
CH ₃ CH=CHCON(C ₆ H ₅) ₂	CH ₃ MgI	<i>i</i> -C ₄ H ₉ CON(C ₆ H ₅) ₂ (1-2%); (C ₆ H ₅) ₂ NCH(CH ₃)CH[CON(C ₆ H ₅) ₂]CO- <i>i</i> -C ₄ H ₉ (?)‡ (principal product)	47

* X = Br, I.

† R = C₂H₅, C₆H₅, C₆H₅CH₂.

‡ Cf. Nenitzescu (64).

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₅O-NRR' (<i>cont.</i>)			
CH ₃ CH=CHCON(C ₆ H ₅) ₂	CH ₃ MgI	<i>i</i> -C ₃ H ₇ CH[CON(C ₆ H ₅) ₂]CH(CH ₃)CH ₂ - CON(C ₆ H ₅) ₂	64
CH ₃ CH=CHCON(C ₆ H ₅) ₂	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)CHCH ₂ CON(C ₆ H ₅) ₂ (quant.)	46
CH ₃ CH=CHCON(C ₆ H ₅) ₂	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅)CHCH=C(OMgBr)N(C ₆ H ₅) ₂ ; CH ₃ (C ₂ H ₅)CHCH[CON(C ₆ H ₅) ₂]CH(CH ₃)- CH ₂ CON(C ₆ H ₅) ₂	65
CH ₃ CH=CHCON(C ₆ H ₅) ₂	C ₆ H ₅ MgBr	CH ₃ (C ₆ H ₅)CHCH ₂ CON(C ₆ H ₅) ₂ (quant.)	46
C₄H₆OBr-NRR'			
C ₂ H ₅ CHBrCON(CH ₃) ₂ (44 g.)	C ₆ H ₅ MgBr (150 g. C ₆ H ₅ Br)	C ₂ H ₅ CH[N(CH ₃) ₂]C(C ₆ H ₅) ₂ OH (1 g.); <i>n</i> -C ₃ H ₇ CON(CH ₃) ₂ (4 g.); <i>n</i> -C ₃ H ₇ COC ₆ H ₅ ; CH ₃ CH=CHCON(CH ₃) ₂ ; (CH ₃) ₂ NH; C ₆ H ₅ Br; (C ₆ H ₅ —) ₂	77
C ₂ H ₅ CHBrCON(C ₂ H ₅) ₂	C ₆ H ₅ MgBr (excess)	<i>n</i> -C ₃ H ₇ CON(C ₂ H ₅) ₂ ; <i>n</i> -C ₃ H ₇ COC ₆ H ₅ (trace); CH ₃ CH=CHCON(C ₂ H ₅) ₂ ; <i>n</i> -C ₃ H ₇ (C ₆ H ₅) ₂ COH	87
C₄H₇ON			
2-Pyrrolidone (43.5 g.)	<i>n</i> -C ₃ H ₇ MgBr (250 ml. C ₃ H ₇ Br)	2-Propylpyrrolidine; dipropylpyrrolidine + C ₁₃ H ₂₅ N, b.p. 125–135° (aggregating 6 g.)	42
C₄H₇O-NRR'			
<i>n</i> -C ₃ H ₇ CONH ₂	CH ₃ MgI (2+ equiv.)	CH ₃ CO- <i>n</i> -C ₃ H ₇ (> 20%, < 50%)	2
<i>n</i> -C ₃ H ₇ CONHC ₆ H ₅	C ₂ H ₅ MgBr* (excess)	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)C=NC ₆ H ₅ (<i>ca.</i> 40%); unsat'd ketone, C ₁₁ H ₂₀ O, b. 99–103°/14 mm.; recovered amide	63

* C₂H₅MgI gave no anil.

TABLE XII-I (Continued)

Co-reactant	RMgX	Product(s)	Ref.
C₄H₇O-NRR' (cont.)			
<i>n</i> -C ₃ H ₇ CONHC ₆ H ₄ -4-CH ₃	C ₂ H ₅ MgBr (excess)	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)C≡NC ₆ H ₄ -4-CH ₃ (ca. 40%)	63
<i>n</i> -C ₃ H ₇ CON(CH ₃) ₂	CH ₃ MgI	<i>n</i> -C ₃ H ₇ (CH ₃) ₂ CN(CH ₃) ₂	59
<i>n</i> -C ₃ H ₇ CON(C ₂ H ₅) ₂	CH ₃ MgI	<i>n</i> -C ₃ H ₇ (CH ₃) ₂ CN(C ₂ H ₅) ₂	59
<i>n</i> -C ₃ H ₇ CON(C ₂ H ₅) ₂ + CH ₃ I	CH ₃ MgI	<i>n</i> -C ₃ H ₇ (CH ₃) ₂ CN(C ₂ H ₅) ₂ ; CH ₃ (C ₂ H ₅)(<i>n</i> -C ₃ H ₇)CN(C ₂ H ₅) ₂ *	60
<i>n</i> -C ₃ H ₇ CON(C ₂ H ₅) ₂ (30 g.) + C ₂ H ₅ I (33 g.)	CH ₃ MgI (92 g. CH ₃ I)	<i>n</i> -C ₃ H ₇ (CH ₃) ₂ CN(C ₂ H ₅) ₂ ; CH ₃ (<i>n</i> -C ₃ H ₇) ₂ CN(C ₂ H ₅) ₂ *	60
<i>n</i> -C ₃ H ₇ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	(C ₂ H ₅) ₂ NC(C ₂ H ₅) ₂ <i>n</i> -C ₃ H ₇	59
<i>n</i> -C ₃ H ₇ CON(C ₂ H ₅)C ₆ H ₅	C ₂ H ₅ MgBr	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)C(OH)CH(C ₂ H ₅)CON- (C ₂ H ₅)C ₆ H ₅	62
<i>n</i> -C ₃ H ₇ CON(C ₂ H ₅)C ₆ H ₅	C ₂ H ₅ MgBr	C ₂ H ₆ ; <i>n</i> -C ₃ H ₇ (C ₂ H ₅) ₂ COH (10-30%); HO(C ₂ H ₅)(<i>n</i> -C ₃ H ₇)CCH(C ₂ H ₅)CON- (C ₂ H ₅)C ₆ H ₅ ; "an ethylenic dehydr'n product"	61
<i>i</i> -C ₃ H ₇ CONH ₂	C ₂ H ₅ MgX (2+ equiv.)	C ₂ H ₅ CO- <i>i</i> -C ₃ H ₇ (> 20%, < 50%)	2
C₅H₃O₂-NRR'			
<i>N,N</i> -Diethyl-2-furoamide	C ₂ H ₅ MgBr	2-Propionylfuran (80-85%)	48
<i>N,N</i> -Diethyl-2-furoamide	<i>n</i> -C ₃ H ₇ MgI	2-Butyrylfuran (80-85%)	48
<i>N</i> -Methyl-2-furoanilide (20 g.)	C ₂ H ₅ MgBr (29 g. C ₂ H ₅ Br)	2-Propionylfuran (4 g.); CH ₃ NHC ₆ H ₅	56
<i>N</i> -Methyl-2-furoanilide	<i>i</i> -C ₄ H ₉ MgCl (27 g. C ₄ H ₉ Cl)	2-Isovaleryl-furan (4 g.)	56
<i>N</i> -Ethyl-2-furoanilide (40 g.)	C ₂ H ₅ MgBr (51 g. C ₂ H ₅ Br)	2-Propionylfuran (13 g.)	56
<i>N</i> -Ethyl-2-furoanilide (46 g.)	<i>i</i> -C ₄ H ₉ MgCl (50 g. C ₄ H ₉ Cl)	2-Isovaleryl-furan (12 g.)	56
<i>N</i> -Ethyl-2-furoanilide (40 g.)	C ₆ H ₅ MgBr (73 g. C ₆ H ₅ Br)	2-Benzoylfuran (7 g.); tertiary base, C ₂₅ H ₂₃ ON (5 g.)	56
<i>N</i> -Ethyl-2-furoanilide (40 g.)	2-CH ₃ C ₆ H ₄ MgBr (69 g. C ₇ H ₇ Br)	2- <i>o</i> -Toluylfuran (5 g.)	56

* Replacement of Et₂O by C₆H₆; four hours reflux.

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₃O₂-NRR' (<i>cont.</i>)			
<i>N,N</i> -Diphenyl-2-furoamide (40 g.)	C ₂ H ₅ MgBr (54 g. C ₂ H ₅ Br)	2-Propionylfuran (15 g.)	56
<i>N,N</i> -Diphenyl-2-furoamide (17 g.)	<i>i</i> -C ₄ H ₉ MgCl (15 g. C ₄ H ₉ Cl)	2-Isovaleryl-furan (9 g.)	56
<i>N,N</i> -Diphenyl-2-furoamide	C ₆ H ₅ MgBr (30 g. C ₆ H ₅ Br)	2-Benzoylfuran (4 g.); (C ₆ H ₅) ₂ NH (3 g.)	56
<i>N,N</i> -Diphenyl-2-furoamide (20 g.)	2-CH ₃ C ₆ H ₄ MgBr (30 g. C ₆ H ₅ Br)	2- <i>o</i> -Toluylfuran (3 g.); (C ₆ H ₅) ₂ NH (5 g.); recovered amide	56
C₅H₆O₂-NR			
<i>N</i> -Methylglutarimide	RMgBr*	1-Methyl-6-hydroxy-6-alkyl-2-piperidone	38
C₅H₆O₂-(NRR')₂			
CH ₂ [CH ₂ CON(C ₂ H ₅) ₂] ₂	C ₂ H ₅ MgX	CH ₂ (CH ₂ COC ₂ H ₅) ₂ (25-30%)	4
CH ₂ [CH ₂ CON(C ₂ H ₅) ₂] ₂	C ₂ H ₅ MgBr	CH ₂ (CH ₂ COC ₂ H ₅) ₂ (20-30%); C ₂ H ₅ CO(CH ₂) ₃ CON(C ₂ H ₅) ₂ ; C ₂ H ₅ CO(CH ₂) ₃ C(C ₂ H ₅) ₂ N(C ₂ H ₅) ₂	5
CH ₂ [CH ₂ CON(C ₂ H ₅) ₂] ₂	<i>n</i> -C ₃ H ₇ MgX	CH ₂ (CH ₂ CO- <i>n</i> -C ₃ H ₇) ₂ (25-30%)	4
C₅H₉O-NRR'			
<i>t</i> -C ₄ H ₉ CONH ₂	C ₆ H ₅ MgBr (3 equiv.)	<i>t</i> -C ₄ H ₉ COC ₄ H ₉ (chiefly); <i>t</i> -C ₄ H ₉ CN ("very little")	68
C₅H₉ON			
2-Piperidone (29 g.)	<i>n</i> -C ₃ H ₇ MgBr (164 g. C ₃ H ₇ Br)	(±)-γ-Coniceine (7.6 g.); C ₁₀ H ₂₂ N ₂ , b.p. 118-122°/11 mm.	42
1-Methyl-2(3 <i>H</i>)-pyrrolone	RMgX†	1-Methyl-2-alkyl-Δ ² -pyrroline; 1-methyl-2,2-dialkylpyrrolidine	35,40
1-Methyl-2(3 <i>H</i>)-pyrrolone	C ₆ H ₅ MgBt	1-Methyl-2-phenyl-Δ ² -pyrroline	35

* R = CH₃, C₂H₅, *n*-C₃H₇, *n*-C₄H₉, *n*-C₅H₁₁, *n*-C₆H₁₃.† R = CH₃, C₂H₅, *n*-C₃H₇.

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₉ON (<i>cont.</i>)			
1-Methyl-2(3 <i>H</i>)-pyrrolone	C ₆ H ₅ CH ₂ MgX	1-Methyl-2-benzyl-Δ ² -pyrroline	37
C₆H₆O₂NR			
<i>N</i> -Phenylcyclobutane-1,2-dicarboximide (5 g., 0.025 mole)	C ₆ H ₅ MgBr (0.025 mole)	<i>cis</i> -2-Benzoylcyclobutanecarboxanilide	18
<i>N</i> -Phenylcyclobutane-1,2-dicarboximide (4 g. 0.02 mole)	C ₆ H ₅ MgBr (0.04 mole)	2-(α-Hydroxybenzhydryl)cyclobutanecarboxanilide	18
C₆H₉ON			
1,5-Dimethyl-2(3 <i>H</i>)-pyrrolone	CH ₃ MgBr	1,2,5-Trimethylpyrrole	36
C₆H₉O₂NRR'			
C ₂ H ₅ COCH ₂ CH ₂ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr (<i>excess</i>)	(C ₂ H ₅) ₂ C(OH)CH ₂ CH ₂ CON(C ₂ H ₅) ₂ (principal product); (—CH ₂ COC ₂ H ₅) ₂ (5%); 2,2,5-triethyldihydrofuran	63
C₆H₁₀O₂N₂			
Sarcosine anhydride*	C ₂ H ₅ MgBr	1,4-Dimethyl-2,2,5,5-tetraethylpiperazine	91
Sarcosine anhydride*	C ₆ H ₅ MgBr	CH ₃ NHCH ₂ COC ₆ H ₅ ; CH ₃ NHCH ₂ CON(CH ₃)CH ₂ COC ₆ H ₅	91
C₆H₁₁O-NRR'			
<i>t</i> -C ₅ H ₁₁ CONH ₂	C ₆ H ₅ MgBr (3 equiv.)	<i>t</i> -C ₅ H ₁₁ COC ₆ H ₅ (chiefly); <i>t</i> -C ₅ H ₁₁ CCN (<i>very little</i>)	68

* 1,4-Dimethyl-2,5-piperazinedione.

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₁O₃-NRR'			
(C ₂ H ₅ O) ₂ CHCON(CH ₂) ₅ (54 g.)	CH ₃ MgI (55 ml. CH ₃ I)	(C ₂ H ₅ O) ₂ CHCOCH ₃ (29.4 g., 80.7%; 70-76%, pure)	83
C₇H₄OCl-NRR'			
2-ClC ₆ H ₄ CONH ₂	2-ClC ₆ H ₄ CH ₂ MgBr (3-4 equiv.)	2-ClC ₆ H ₄ COCH ₂ C ₆ H ₄ -2-Cl (70%)	29
2-ClC ₆ H ₄ CONH ₂ (0.025 mole)	3-ClC ₆ H ₄ CH ₂ MgBr (0.10 mole C ₇ H ₆ BrCl)	2-ClC ₆ H ₄ COCH ₂ C ₆ H ₄ -3-Cl (78%)	26
2-ClC ₆ H ₄ CONH ₂	4-ClC ₆ H ₄ CH ₂ MgBr (3-4 equiv.)	2-ClC ₆ H ₄ COCH ₂ C ₆ H ₄ -4-Cl (72%)	29
2-ClC ₆ H ₄ CONH ₂	C ₆ H ₅ CH ₂ MgCl (3-4 equiv.)	2-ClC ₆ H ₄ COCH ₂ C ₆ H ₅ (71%)	29
3-ClC ₆ H ₄ CONH ₂ (0.025 mole)	2-ClC ₆ H ₄ CH ₂ MgBr (0.10 mole C ₇ H ₆ BrCl)	3-ClC ₆ H ₄ COCH ₂ C ₆ H ₄ -2-Cl (61%)	26
3-ClC ₆ H ₄ CONH ₂ (0.025 mole)	3-ClC ₆ H ₄ CH ₂ MgBr (0.10 mole C ₇ H ₆ BrCl)	3-ClC ₆ H ₄ COCH ₂ C ₆ H ₄ -3-Cl (79%)	26
3-ClC ₆ H ₄ CONH ₂ (0.025 mole)	4-ClC ₆ H ₄ CH ₂ MgBr (0.10 mole C ₇ H ₆ BrCl)	3-ClC ₆ H ₄ COCH ₂ C ₆ H ₄ -4-Cl (85%)	26
3-ClC ₆ H ₄ CONH ₂	C ₆ H ₅ CH ₂ MgCl (3-4 equiv.)	3-ClC ₆ H ₄ COCH ₂ C ₆ H ₅ (72%)	25, 26
4-ClC ₆ H ₄ CONH ₂	2-ClC ₆ H ₄ CH ₂ MgBr (3-4 equiv.)	4-ClC ₆ H ₄ COCH ₂ C ₆ H ₄ -2-Cl (80%)	29
4-ClC ₆ H ₄ CONH ₂ (0.025 mole)	3-ClC ₆ H ₄ CH ₂ MgBr (0.10 mole C ₇ H ₆ BrCl)	4-ClC ₆ H ₄ COCH ₂ C ₆ H ₄ -3-Cl (60%)	26
4-ClC ₆ H ₄ CONH ₂	4-ClC ₆ H ₄ CH ₂ MgBr	4-ClC ₆ H ₄ COCH ₂ C ₆ H ₄ -4-Cl (74%)	29
4-ClC ₆ H ₄ CONH ₂ (7.78 g.)	C ₆ H ₅ CH ₂ MgCl (25.3 g. C ₇ H ₇ Cl)	4-ClC ₆ H ₄ COCH ₂ C ₆ H ₅ (77%)	29, 27
C₇H₄O₃S-NR			
N-Methylsaccharin	CH ₃ MgBr	2-[HO(CH ₃) ₂ C]C ₆ H ₄ SO ₂ NHCH ₃	71
N-Methylsaccharin	C ₂ H ₅ MgBr	2-[HO(C ₂ H ₅) ₂ C]C ₆ H ₄ SO ₂ NHCH ₃	71
N-Methylsaccharin	<i>i</i> -C ₃ H ₇ MgBr	2-[HO(<i>i</i> -C ₃ H ₇) ₂ C]C ₆ H ₄ SO ₂ NHCH ₃	71
N-Methylsaccharin	<i>i</i> -C ₅ H ₁₁ MgBr	2-[HO(<i>i</i> -C ₅ H ₁₁) ₂ C]C ₆ H ₄ SO ₂ NHCH ₃	71

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₄O₃S-NR (cont.)			
N-Methylsaccharin	C ₆ H ₅ MgBr	2-[HO(C ₆ H ₅) ₂ C]C ₆ H ₄ SO ₂ NHCH ₃	71
N-Ethylsaccharin (12 g.)	CH ₃ MgBr* (50 g. CH ₃ Br)	2-[HO(CH ₃) ₂ C]C ₆ H ₄ SO ₂ NHC ₂ H ₅	71
N-Ethylsaccharin	C ₂ H ₅ MgBr	2-[HO(C ₂ H ₅) ₂ C]C ₆ H ₄ SO ₂ NHC ₂ H ₅ (quant.)	70,71
N-Ethylsaccharin	<i>i</i> -C ₃ H ₇ MgBr	2-[HO(<i>i</i> -C ₃ H ₇) ₂ C]C ₆ H ₄ SO ₂ NHC ₂ H ₅	71
N-Ethylsaccharin	<i>i</i> -C ₃ H ₁₁ MgBr	2-[HO(<i>i</i> -C ₃ H ₁₁) ₂ C]C ₆ H ₄ SO ₂ NHC ₂ H ₅	71
N-Ethylsaccharin	C ₆ H ₅ MgBr (2-3 equiv.)	2-[HO(C ₆ H ₅) ₂ C]C ₆ H ₄ SO ₂ NHC ₂ H ₅ (ca. quant.)	70,71
C₇H₅O-NRR'			
C ₆ H ₅ CONH ₂	CH ₃ MgI (2+ equiv.)	CH ₃ COC ₆ H ₅ (ca. 50%)	2
C ₆ H ₅ CONH ₂	C ₂ H ₅ MgBr	C ₂ H ₅ COC ₆ H ₅	43
C ₆ H ₅ CONH ₂	C ₂ H ₅ MgX† (2+ equiv.)	C ₂ H ₅ COC ₆ H ₅ (ca. 50%)	2
C ₆ H ₅ CONH ₂	2-ClC ₆ H ₄ CH ₂ MgBr (3-4 equiv.)	C ₆ H ₅ COCH ₂ C ₆ H ₄ -2-Cl (73%)	29
C ₆ H ₅ CONH ₂ (0.025 mole)	3-ClC ₆ H ₄ CH ₂ MgBr (0.10 mole C ₇ H ₆ BrCl)	C ₆ H ₅ COCH ₂ C ₆ H ₄ -3-Cl (42%)	26
C ₆ H ₅ CONH ₂	4-ClC ₆ H ₄ CH ₂ MgBr (3-4 equiv.)	C ₆ H ₅ COCH ₂ C ₆ H ₄ -4-Cl (70%)	29,27
C ₆ H ₅ CONH ₂	C ₆ H ₅ CH ₂ MgCl (3-4 equiv.)	C ₆ H ₅ COCH ₂ C ₆ H ₅ (77%)	25
C ₆ H ₅ CON(C ₂ H ₅) ₂ (55 g.)	C ₂ H ₅ MgBr (110 g. C ₂ H ₅ Br)	C ₂ H ₅ COC ₆ H ₅ (13 g., 31%)‡	45
C ₆ H ₅ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	C ₂ H ₅ COC ₆ H ₅ (55%)§	45
C ₆ H ₅ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	C ₂ H ₅ COC ₆ H ₅ (60%)¶	45
C ₆ H ₅ CON(C ₂ H ₅) ₂	C ₆ H ₅ MgBr	Quant. recovery of amide‡	45
C ₆ H ₅ CON(C ₂ H ₅) ₂ (10 g.)	C ₆ H ₅ MgBr (22 g. C ₆ H ₅ Br)	Recovered amide (8 g.)‡	57

* The use of CH₃MgI leads to liberation of I₂ in large quantities.

† X = Br, I.

‡ Twelve hours standing in Et₂O.

§ Four hours reflux in C₆H₆, with stirring.

¶ Four hours reflux in CH₃C₆H₅, with stirring.

‡ Fifteen hours reflux in Et₂O.

TABLE XII-I (Continued)

Co-reactant	RMgX	Product(s)	Ref.
C₇H₅O-NRR' (<i>cont.</i>)			
C ₆ H ₅ CON(C ₂ H ₅) ₂ (30 g.)	C ₆ H ₅ CH ₂ MgCl (64 g. C ₇ H ₇ Cl)	C ₆ H ₅ COCH ₂ C ₆ H ₅ (21%)*	45
C ₆ H ₅ CON(C ₂ H ₅) ₂	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ COCH ₂ C ₆ H ₅ (31%)†	45
C ₆ H ₅ CON(C ₂ H ₅) ₂	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ COCH ₂ C ₆ H ₅ (33%)‡	45
C ₆ H ₅ CON(C ₂ H ₅)C ₆ H ₅ (4 g.)	C ₆ H ₅ MgBr (7 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ CN(C ₂ H ₅)C ₆ H ₅ ; (C ₆ H ₅) ₂ CO; C ₂ H ₅ NHC ₆ H ₅	12
C ₆ H ₅ CONHNHC ₆ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ C=NNHC ₆ H ₅ ; (C ₆ H ₅) ₂ C=NC ₆ H ₅ ; (C ₆ H ₅) ₂ C=NH; (C ₆ H ₅) ₂ CO	20
C₇H₅O₂-NRR'			
2-HOC ₆ H ₄ CONH ₂ (14 g.)	C ₂ H ₅ MgBr (68 g. C ₂ H ₅ Br)	C ₂ H ₅ COC ₆ H ₄ -2-OH (trace); recovered amide§	15
2-HOC ₆ H ₄ CONH ₂ (14 g.)	C ₂ H ₅ MgBr (68 g. C ₂ H ₅ Br)	C ₂ H ₅ COC ₆ H ₄ -2-OH (5.5 g., 30%); recovered amide¶	15
2-HOC ₆ H ₄ CON(C ₂ H ₅) ₂ (30 g.)	C ₂ H ₅ MgBr (68 g. C ₂ H ₅ Br)	C ₂ H ₅ COC ₆ H ₄ -2-OH (10-12 g., <i>ca.</i> 45%); recovered amide (4 g.)‡	15
2-HOC ₆ H ₄ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	C ₂ H ₅ COC ₆ H ₄ -2-OH (82-84%)**	15,14
3-HOC ₆ H ₄ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	C ₂ H ₅ COC ₆ H ₄ -3-OH (10%); recovered amide**	15
3-HOC ₆ H ₄ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	C ₂ H ₅ COC ₆ H ₄ -3-OH (75%); recovered amide††	15

* Twelve hours standing in Et₂O.† Four hours reflux in C₆H₆, with stirring.‡ Four hours reflux in CH₃C₆H₅, with stirring.§ Six hours reflux, twelve hours standing in Et₂O.¶ Six hours reflux, twelve hours standing in Et₂O-C₆H₆.‡ Five hours reflux in Et₂O.** Six hours reflux at 60-70° in Et₂O-C₆H₆.†† Four hours reflux in *n*-Bu₂O.

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₅O₂-NRR' (<i>cont.</i>)			
4-HOC ₆ H ₄ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	C ₂ H ₅ COC ₆ H ₄ -4-OH (5%); recovered amide*	15,14
4-HOC ₆ H ₄ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	C ₂ H ₅ COC ₆ H ₄ -4-OH (65%); recovered amide†	15
<i>N,N</i> -Diethyl-β-2-furylacrylamide (20 g.)	C ₂ H ₅ MgBr (25 g. C ₂ H ₅ Br)	<i>N,N</i> -Diethyl-β-2-furylvaleramide (70%)	55
<i>N,N</i> -Diethyl-β-2-furylacrylamide (20 g.)	C ₆ H ₅ MgBr (36 g. C ₆ H ₅ Br)	<i>N,N</i> -Diethyl-β-2-furylhydrocinnamamide (78%)	55
<i>N</i> -Methyl-β-2-furylacrylanilide	C ₂ H ₅ MgBr	<i>N</i> -Methyl-β-2-furylvaleranimide (68%)	55
<i>N</i> -Methyl-β-2-furylacrylanilide	C ₆ H ₅ MgBr	<i>N</i> -Methyl-β-2-furylhydrocinnamanimide (70%)	55
<i>N</i> -Ethyl-β-2-furylacrylanilide	C ₂ H ₅ MgBr	<i>N</i> -Ethyl-β-2-furylvaleranimide	55
<i>N</i> -Ethyl-β-2-furylacrylanilide	C ₆ H ₅ MgBr	<i>N</i> -Ethyl-β-2-furylhydrocinnamanimide (70%)	55
<i>N,N</i> -Diphenyl-β-2-furylacrylamide (17 g.)	C ₂ H ₅ MgBr (19 g. C ₂ H ₅ Br)	<i>N,N</i> -Diphenyl-β-2-furylvaleramide (90%); (C ₆ H ₅) ₂ NH	55
<i>N,N</i> -Diphenyl-β-2-furylacrylamide (25 g.)	<i>n</i> -C ₃ H ₇ MgBr (36 g. C ₃ H ₇ Br)	<i>N,N</i> -Diphenyl-β-2-furylcaproamide	55
<i>N,N</i> -Diphenyl-β-2-furylacrylamide (17 g.)	C ₆ H ₅ MgBr (21 g. C ₆ H ₅ Br)	<i>N,N</i> -Diphenyl-β-2-furylhydrocinnamamide (95%)	55
C₇H₅O₃-NRR'			
2,4-(HO) ₂ C ₆ H ₃ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr (5 equiv.)	C ₂ H ₅ COC ₆ H ₃ -2,4-(OH) ₂ (12%)	15,14
3,4-(HO) ₂ C ₆ H ₃ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr (6 equiv.)	No reaction in C ₆ H ₆ ; resinification in <i>n</i> -Bu ₂ O	15
C₇H₅O₄-NRR'			
3,4,5-(HO) ₃ C ₆ H ₂ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr (6 equiv.)	No reaction in C ₆ H ₆ ; resinification in <i>n</i> -Bu ₂ O	15

* Six hours reflux at 60–70° in Et₂O-C₆H₆.† Four hours reflux in *n*-Bu₂O.

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₀O₂-NR			
<i>N</i> , <i>β</i> , <i>β</i> -Trimethylglutarimide	<i>n</i> -C ₇ H ₁₅ MgBr	After hydrolysis: <i>n</i> -C ₇ H ₁₅ COCH ₂ C(CH ₃) ₂ CH ₂ CO ₂ H	3
C₇H₁₁ON			
1-Methyl-5-ethyl-2(3 <i>H</i>)-pyrrolone	CH ₃ MgBr (3 equiv.)	1,2-Dimethyl-5-ethylpyrrole (38%)	36
1-Methyl-5-ethyl-2(3 <i>H</i>)-pyrrolone	C ₂ H ₅ MgBr (2 equiv.)	1-Methyl-2,5-diethylpyrrole; (C ₂ H ₅ COCH ₂ —) ₂ ; 1-methyl-2,2,5-triethyl- Δ^2 -pyrroline; C ₂ H ₆	36
1-Methyl-5-ethyl-2(3 <i>H</i>)-pyrrolone	C ₆ H ₅ CH ₂ MgCl	1-Methyl-2-ethyl-5-benzylpyrrole (29%); C ₂ H ₅ COCH ₂ CH ₂ COCH ₂ C ₆ H ₅ (71%)	36
3,3,5-Trimethyl-2-pyrrolidone	RMgX	"Did not react"	67
C₇H₁₃ON			
1-Methyl-2-oxo-1-azacycloheptane	CH ₃ MgI	1,2,2-Trimethyl-1-azacycloheptane	41
1-Methyl-2-oxo-1-azacycloheptane	C ₂ H ₅ MgBr	1-Methyl-2,2-diethyl-1-azacycloheptane	41
1-Methyl-2-oxo-1-azacycloheptane	C ₆ H ₅ MgBr	1-Methyl-2-phenyl-2-hydroxy-1-azocycloheptane (?) or 1-methylamino-6-phenylhexanone (?)	41
1-Methyl-2-oxo-1-azacycloheptane	C ₆ H ₅ CH ₂ MgCl	Methyldibenzylazacycloheptane hydrochloride	41
1-Methyl-2-oxo-1-azacycloheptane	1-C ₁₀ H ₇ MgBr	1-Methyl-2- α -naphthyl-1-azacycloheptane	41
C₈H₄O₂-NR			
Phthalimide	C ₂ H ₅ MgBr	3-Ethylisoindolone	2
Phthalimide	<i>i</i> -C ₄ H ₉ MgX	3-Isobutylisoindolone	2
Phthalimide	<i>i</i> -C ₅ H ₁₁ MgX	3-Isoamylisoindolone	2
<i>N</i> -Ethylphthalimide (10 g.)	CH ₃ MgBr (20 g. CH ₃ Br)	2-Ethyl-3-hydroxy-3-methylphthalimidine ("good yield")	70

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₄O₂-NR (cont.)			
<i>N</i> -Ethylphthalimide	C ₂ H ₅ MgBr	2,3-Diethyl-3-hydroxyphthalimidine (“very good yield”)	70
<i>N</i> -Ethylphthalimide	C ₆ H ₅ MgBr	2-Ethyl-3-hydroxy-3-phenylphthalimidine	70
C₆H₄O₂-(NRR')₂			
C ₆ H ₄ -1,2-[CON(C ₂ H ₅) ₂] ₂ (40 g.)	C ₂ H ₅ MgBr (110 g. C ₂ H ₅ Br)	3,3-Diethylphthalide (15%); 2-C ₂ H ₅ COC ₆ H ₄ CON(C ₂ H ₅) ₂ (10%); recovered amide	45
C ₆ H ₄ -1,2-[CON(C ₂ H ₅) ₂] ₂	C ₆ H ₅ MgBr	No reaction	45
C ₆ H ₄ -1,3-[CON(C ₂ H ₅) ₂] ₂ (45 g.)	C ₂ H ₅ MgBr (110 g. C ₂ H ₅ Br)	3-C ₂ H ₅ COC ₆ H ₄ CON(C ₂ H ₅) ₂ (20%); 1,3- (C ₂ H ₅ CO) ₂ C ₆ H ₄ (25%); recovered amide	45
C ₆ H ₄ -1,3-[CON(C ₂ H ₅) ₂] ₂	C ₆ H ₅ MgBr	No reaction	45
C ₆ H ₄ -1,4-[CON(C ₂ H ₅) ₂] ₂ (40 g.)	C ₂ H ₅ MgBr (110 g. C ₂ H ₅ Br)	4-C ₂ H ₅ COC ₆ H ₄ CON(C ₂ H ₅) ₂ (25%); 1,4- (C ₂ H ₅ CO) ₂ C ₆ H ₄ (30%); recovered amide	45
C ₆ H ₄ -1,4-[CON(C ₂ H ₅) ₂] ₂	C ₆ H ₅ MgBr	No reaction	45
C₆H₄O₂N-NRR'			
Benzoxazole-2-carboxanilide (10 g.)	CH ₃ MgI (1.5 equiv.)	Benzoxazole-2-carboxaldehyde anil	73
C₆H₅O₃-NRR'			
2-HO ₂ CC ₆ H ₄ CON(C ₂ H ₅) ₂ (30 g.)	C ₂ H ₅ MgBr (110 g. C ₂ H ₅ Br)	3,3-Diethylphthalide (26 g., 80%)	45
2-HO ₂ CC ₆ H ₄ CON(C ₂ H ₅) ₂ (20 g.)	<i>n</i> -C ₃ H ₇ MgBr (66 g. C ₃ H ₇ Br)	3,3-Di- <i>n</i> -propylphthalide (15 g.)	49
2-HO ₂ CC ₆ H ₄ CON(C ₂ H ₅) ₂ (19 g.)	<i>i</i> -C ₄ H ₉ MgCl (53 g. C ₄ H ₉ Cl)	3,3-Diisobutylphthalide (15 g.)	49
2-HO ₂ CC ₆ H ₄ CON(C ₂ H ₅) ₂ (20 g.)	<i>i</i> -C ₅ H ₁₁ MgBr (90 g. C ₅ H ₁₁ Br)	3,3-Diisoamylphthalide (15 g.)	49
2-HO ₂ CC ₆ H ₄ CON(C ₂ H ₅) ₂ (20 g.)	C ₆ H ₅ MgBr (94 g. C ₆ H ₅ Br)	3,3-Diphenylphthalide (16 g.)	49
2-HO ₂ CC ₆ H ₄ CON(C ₂ H ₅) ₂ (20 g.)	C ₆ H ₅ CH ₂ MgCl (75 g. C ₇ H ₇ Cl)	3,3-Dibenzylphthalide (17 g.)	49

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₅OCl-NRR'			
DL-C ₆ H ₅ CHClCONH ₂ (12 g.)	C ₆ H ₅ MgBr (91 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ CHCOC ₆ H ₅ (small yield)	74
C₆H₅O₂Cl-NRR'			
3-ClC ₆ H ₄ CH(OH)CONH ₂ (4.64 g.)	4-CH ₃ OC ₆ H ₄ MgBr (18.70 g. C ₇ H ₇ BrO)	4-CH ₃ OC ₆ H ₄ COCH(OH)C ₆ H ₄ -3-Cl (30%)	30
4-ClC ₆ H ₄ CH(OH)CONH ₂ (1.3 g.)	4-(CH ₃) ₂ NC ₆ H ₄ MgBr (20 g. C ₈ H ₁₀ BrN)	β-4-(CH ₃) ₂ NC ₆ H ₄ COCH(OH)C ₆ H ₄ -4-Cl (0.5 g.)	23
C₆H₇O-NRR'			
C ₆ H ₅ CH ₂ CONH ₂ (38 g.)	C ₂ H ₅ MgBr (120 g. C ₂ H ₅ Br)	Recovered amide; C ₂ H ₅ COCH ₂ C ₆ H ₅ (39%)	45
C ₆ H ₅ CH ₂ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgX*	No reaction	45
C ₆ H ₅ CH ₂ CON(C ₂ H ₅) ₂ (30 g.)	C ₆ H ₅ MgBr (60 g. C ₆ H ₅ Br)	(C ₆ H ₅ —); recovered amide; C ₆ H ₅ COCH ₂ C ₆ H ₅ (37%)	45
C₆H₇O₂-NRR'			
C ₆ H ₅ CH(OH)CONH ₂ (10.0 g.)	CH ₃ MgI (70.5 g. CH ₃ I)	CH ₃ COCH(OH)C ₆ H ₅ (8 g., crude)	66
DL-C ₆ H ₅ CH(OH)CONH ₂ (20.0 g.)	CH ₃ MgI (111.2 g. CH ₃ I)	DL-C ₆ H ₅ CH(OH)COCH ₃ (3.5 g.)	84,79
C ₆ H ₅ CH(OH)CONH ₂	C ₂ H ₅ MgBr (4 equiv.)	C ₂ H ₅ COCH(OH)C ₆ H ₅ (ca. 40%)	79
D(–)-C ₆ H ₅ CH(OH)CONH ₂ (15 g.)	C ₂ H ₅ MgBr (from 50 g. bromide)	D(–)-C ₆ H ₅ CH(OH)COC ₂ H ₅	69
C ₆ H ₅ CH(OH)CONH ₂ (25 g.)	C ₂ H ₅ MgI	C ₂ H ₅ COCH(OH)C ₆ H ₅ (10 g.)	66
C ₆ H ₅ CH(OH)CONH ₂	<i>n</i> -C ₃ H ₇ MgBr (4 equiv.)	<i>n</i> -C ₃ H ₇ COCH(OH)C ₆ H ₅ (30%)	79
C ₆ H ₅ CH(OH)CONH ₂	<i>i</i> -C ₃ H ₇ MgBr (4 equiv.)	<i>i</i> -C ₃ H ₇ COCH(OH)C ₆ H ₅ (28–30%)	79
C ₆ H ₅ CH(OH)CONH ₂	<i>n</i> -C ₄ H ₉ MgBr (4 equiv.)	<i>n</i> -C ₄ H ₉ COCH(OH)C ₆ H ₅ (20%)	79
C ₆ H ₅ CH(OH)CONH ₂	<i>i</i> -C ₄ H ₉ MgBr (4 equiv.)	<i>i</i> -C ₄ H ₉ COCH(OH)C ₆ H ₅ (17%)	79
C ₆ H ₅ CH(OH)CONH ₂ (15.8 g.)	C ₆ H ₅ MgBr (62 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH(OH)C ₆ H ₅	66
D-C ₆ H ₅ CH(OH)CONH ₂	C ₆ H ₅ MgBr	D-C ₆ H ₅ CH(OH)COC ₆ H ₅	84
C ₆ H ₅ CH(OH)CONH ₂	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ COCH(OH)C ₆ H ₅ (30%)	79
D(–)-C ₆ H ₅ CH(OH)CONH ₂ (8 g.)	C ₆ H ₅ CH ₂ MgCl (32 g. C ₇ H ₇ Cl)	D(–)-C ₆ H ₅ CH(OH)COCH ₂ C ₆ H ₅	69
DL-C ₆ H ₅ CH(OH)CONH ₂	2-CH ₃ C ₆ H ₄ MgBr	DL-C ₆ H ₅ CH(OH)COC ₆ H ₄ -2-CH ₃ ("very small yield")	58

* X = Br, I.

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₅O₂NRR' (cont.)			
DL-C ₆ H ₅ CH(OH)CONH ₂ (5 g.)	4-CH ₃ C ₆ H ₄ MgBr (34 g. C ₇ H ₇ Br)	DL-C ₆ H ₅ CH(OH)COC ₆ H ₄ -4-CH ₃ (0.5 g.)	58
C ₆ H ₅ CH(OH)CONH ₂ (3 g.)	4-CH ₃ OC ₆ H ₄ MgBr (22.4 g. C ₇ H ₇ BrO)	4-CH ₃ OC ₆ H ₄ COCH(OH)C ₆ H ₅ (1.5 g.)	24
DL-C ₆ H ₅ CH(OH)CONHC ₂ H ₅	C ₆ H ₅ MgBr	"No success"	58
DL-C ₆ H ₅ CH(OH)CON(CH ₂) ₅	C ₆ H ₅ MgX*	DL-C ₆ H ₅ CH(OH)COC ₆ H ₅ ; DL-C ₆ H ₅ CH(OH)C(C ₆ H ₅) ₂ OH	58
2-CH ₃ OC ₆ H ₄ CONH ₂	C ₂ H ₅ MgBr	2-CH ₃ OC ₆ H ₄ COC ₂ H ₅ (70%); 2-CH ₃ OC ₆ H ₄ C(=NH)C ₂ H ₅	14 14
2-CH ₃ OC ₆ H ₄ CONH ₂ (22.5 g.)	C ₂ H ₅ MgBr (55 g. C ₂ H ₅ Br)	C ₂ H ₅ COC ₆ H ₄ -2-OCH ₃ (49%); recovered amide (40-50%)†	15
2-CH ₃ OC ₆ H ₄ CON(C ₂ H ₅) ₂ (21 g.)	C ₂ H ₅ MgBr (24 g. C ₂ H ₅ Br)	2-CH ₃ OC ₆ H ₄ (C ₂ H ₅) ₂ CN(C ₂ H ₅) ₂ (?); C ₂ H ₅ COC ₆ H ₄ -2-OCH ₃ (84%); recovered amide‡	15
2-CH ₃ OC ₆ H ₄ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	2-CH ₃ OC ₆ H ₄ COC ₂ H ₅ (60-80%)	14
4-CH ₃ OC ₆ H ₄ CONH ₂ (20 g.)	C ₂ H ₅ MgBr (55 g. C ₂ H ₅ Br)	C ₂ H ₅ C(=NH)C ₆ H ₄ -4-OCH ₃ ; C ₂ H ₅ COC ₆ H ₄ -4-OCH ₃ (70%); recovered amide	14, 15, 13
4-CH ₃ OC ₆ H ₄ CONH ₂	2-ClC ₆ H ₄ CH ₂ MgBr (3-4 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ C ₆ H ₄ -4-Cl (55%)	25
4-CH ₃ OC ₆ H ₄ CONH ₂	3-ClC ₆ H ₄ CH ₂ MgBr (4 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ C ₆ H ₄ -3-Cl (60%)	30
4-CH ₃ OC ₆ H ₄ CONH ₂	4-ClC ₆ H ₄ CH ₂ MgBr (3-4 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ C ₆ H ₄ -4-Cl (66%)	25, 28
4-CH ₃ OC ₆ H ₄ CONH ₂	C ₆ H ₅ CH ₂ MgCl (3-4 equiv.)	4-CH ₃ OC ₆ H ₄ COCH ₂ C ₆ H ₅ (70-76%)	24, 25, 27
4-CH ₃ OC ₆ H ₄ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	C ₂ H ₅ COC ₆ H ₄ -4-OCH ₃ ("very little")§	15

* X = Br, I.

† Four hours at 65°.

‡ Five hours at 50°.

§ Reaction in Et₂O.

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₇O₂NRR' (<i>cont.</i>)			
4-CH ₃ OC ₆ H ₄ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	4-CH ₃ OC ₆ H ₄ COC ₂ H ₅ (60–80%)	14
4-CH ₃ OC ₆ H ₄ CON(C ₂ H ₅) ₂ (50 g.)	C ₂ H ₅ MgBr (2.2 equiv.)	4-CH ₃ OC ₆ H ₄ (C ₂ H ₅) ₂ CN(C ₂ H ₅) ₂ (14 g., crude); C ₂ H ₅ COC ₆ H ₄ -4-OCH ₃ (12 g., 30%)*	15
4-CH ₃ OC ₆ H ₄ CON(C ₂ H ₅) ₂ (31 g.)	C ₆ H ₅ MgBr (71 g. C ₆ H ₅ Br)	4-CH ₃ OC ₆ H ₄ (C ₆ H ₅) ₂ CN(C ₂ H ₅) ₂ ·HCl (11 g., 22%); C ₆ H ₅ OH; (C ₆ H ₅ —) ₂ ; recovered amide	15
4-CH ₃ OC ₆ H ₄ CON(C ₂ H ₅) ₂	C ₆ H ₅ MgBr	4-CH ₃ OC ₆ H ₄ COC ₆ H ₅ ; 4-CH ₃ OC ₆ H ₄ (C ₆ H ₅) ₂ CN(C ₂ H ₅) ₂	14
C₈H₁₃O₂NRR'			
<i>n</i> -C ₆ H ₁₃ CH(OH)CONH ₂ (65 g.)	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ COCH(OH)- <i>n</i> -C ₆ H ₁₃ (36 g.)	66
<i>n</i> -C ₆ H ₁₃ CH(OH)CONH ₂ (20 g.)	<i>n</i> -C ₄ H ₉ MgBr (137 g. C ₄ H ₉ Br)	<i>n</i> -C ₄ H ₉ COCH(OH)- <i>n</i> -C ₆ H ₁₃	66
C₉H₇O-NRR'			
C ₆ H ₅ CH=CHCONH ₂	C ₂ H ₅ MgBr	Unidentified H ₂ O-insol., Et ₂ O-insol. syrup	45
C ₆ H ₅ CH=CHCON(C ₂ H ₅) ₂ (45 g.)	C ₂ H ₅ MgBr (55 g. C ₂ H ₅ Br)	C ₆ H ₅ CH(C ₂ H ₅)CH ₂ CON(C ₂ H ₅) ₂ (80%; 82% in C ₆ H ₆ sol'n)	45
C ₆ H ₅ CH=CHCON(C ₂ H ₅) ₂ (45 g.)	C ₆ H ₅ MgBr (80 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ CHCH ₂ CON(C ₂ H ₅) ₂ (83%)	45
C ₆ H ₅ CH=CHCONRC ₆ H ₅ †	CH ₃ MgI	CH ₃ COCH=CHC ₆ H ₅ ; RNHC ₆ H ₅ ; recovered amide	50
C ₆ H ₅ CH=CHCON(CH ₃)C ₆ H ₅	C ₂ H ₅ MgBr	C ₂ H ₅ CH(C ₆ H ₅)CH ₂ CON(CH ₃)C ₆ H ₅ (quant.)	50
C ₆ H ₅ CH=CHCON(CH ₃)C ₆ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH ₂ CON(CH ₃)C ₆ H ₅ (quant.)	50
C ₆ H ₅ CH=CHCON(C ₂ H ₅)C ₆ H ₅	C ₂ H ₅ MgBr	C ₂ H ₅ CH(C ₆ H ₅)CH ₂ CON(C ₂ H ₅)C ₆ H ₅ (quant.)	50
C ₆ H ₅ CH=CHCON(C ₂ H ₅)C ₆ H ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH ₂ CON(C ₂ H ₅)C ₆ H ₅ (quant.)	50,22

* Reaction in C₆H₆.† R = CH₃, C₂H₅, C₆H₅.

TABLE XII - I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₇O-NRR' (<i>cont.</i>)			
C ₆ H ₅ CH=CHCON(C ₆ H ₅) ₂	C ₂ H ₅ MgBr	C ₂ H ₅ CH(C ₆ H ₅)CH ₂ CON(C ₆ H ₅) ₂ (quant.)	50
C ₆ H ₅ CH=CHCON(C ₆ H ₅) ₂	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CHCH ₂ CON(C ₆ H ₅) ₂ (quant.)	50
C₉H₇O₂N			
N-Methylisatin (0.05 mole)	C ₆ H ₅ MgBr (0.25 mole)	1-Methyl-2,3-epoxy-2,3-diphenylindoline (<i>ca.</i> 52%); 1-methyl-3,3-diphenyloxindole	89
C₉H₅O-NRR'			
C ₆ H ₅ (CH ₂) ₂ CON(C ₂ H ₅) ₂ (30 g.)	C ₂ H ₅ MgBr (100 g. C ₂ H ₅ Br)	Recovered amide; C ₂ H ₅ CO(CH ₂) ₂ C ₆ H ₅ (12 g., 50%)	45,43
C ₆ H ₅ (CH ₂) ₂ CON(C ₂ H ₅) ₂	C ₆ H ₅ MgBr	C ₆ H ₅ CO(CH ₂) ₂ C ₆ H ₅	43
C ₆ H ₅ (CH ₂) ₂ CON(C ₂ H ₅) ₂ (30 g.)	C ₆ H ₅ MgBr (5 g. C ₆ H ₅ Br)	Recovered amide; C ₆ H ₅ CO(CH ₂) ₂ C ₆ H ₅ (69%)	45
CH ₃ (C ₆ H ₅)CHCONH ₂ (16 g.)	C ₆ H ₅ MgBr (2.5 equiv.)	C ₆ H ₅ COCH(CH ₃)C ₆ H ₅ (24%); CH ₃ (C ₆ H ₅)CHCN; (C ₆ H ₅ —) ₂	10
CH ₃ (C ₆ H ₅)CHCONH ₂ (27.5 g.)	4-CH ₃ C ₆ H ₄ MgBr (2.5 equiv.)	CH ₃ (C ₆ H ₅)CHCOC ₆ H ₄ -4-CH ₃ (8.5 g.); CH ₃ (C ₆ H ₅)CHCN; (4-CH ₃ C ₆ H ₄ —) ₂ ; resin	10,9
CH ₃ (C ₆ H ₅)CHCONH ₂ (23 g.)	4-CH ₃ OC ₆ H ₄ MgBr (2.5 equiv.)	CH ₃ (C ₆ H ₅)CHCOC ₆ H ₄ -4-OCH ₃ (7 g.); CH ₃ (C ₆ H ₅)CHCN; (4-CH ₃ OC ₆ H ₄ —) ₂	10,9
C₉H₅O₂-NRR'			
C ₆ H ₅ CH ₂ OCH ₂ CONH ₂	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ OCH ₂ COCH ₂ C ₆ H ₅	17
4-CH ₃ OC ₆ H ₄ CH ₂ CONH ₂ (1.2 g.)	3-ClC ₆ H ₄ MgI (7.2 g. C ₆ H ₄ ICI)	3-ClC ₆ H ₄ COCH ₂ C ₆ H ₄ -4-OCH ₃ (20%)	30
4-CH ₃ OC ₆ H ₄ CH ₂ CONH ₂ (11.0 g.)	4-ClC ₆ H ₄ MgBr (38.3 g. C ₆ H ₄ BrCl)	4-ClC ₆ H ₄ COCH ₂ C ₆ H ₄ -4-OCH ₃ (23%)	28
4-CH ₃ OC ₆ H ₄ CH ₂ CONH ₂ (4.13 g.)	C ₆ H ₅ MgBr (15.7 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH ₂ C ₆ H ₄ -4-OCH ₃ (1.85 g., 30%)	27
L-C ₆ H ₅ CH(OCH ₃)CONH ₂ (5.5 g.)	C ₆ H ₅ MgBr (20 g. C ₆ H ₅ Br)	(C ₆ H ₅ —) ₂ ; recovered amide; C ₆ H ₅ CH(OCH ₃)COC ₆ H ₅ (0.35 g., crude)	58

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₉O₂-NRR' (cont.)			
D-, L-, or DL- C ₆ H ₅ CH(OH)CH ₂ CONH ₂	C ₆ H ₅ MgBr	"Unsuccessful"	58
D-C ₆ H ₅ CH ₂ CH(OH)CONH ₂ (5 g.)	C ₆ H ₅ MgBr (29 g. C ₆ H ₅ Br)	D-C ₆ H ₅ CH ₂ CH(OH)COC ₆ H ₅ (2.5 g.)	58
DL-C ₆ H ₅ CH ₂ CH(OH)CONH ₂ (5 g.)	C ₆ H ₅ MgBr (23 g. C ₆ H ₅ Br)	DL-C ₆ H ₅ CH ₂ CH(OH)COC ₆ H ₅ (1.5 g.); DL-C ₆ H ₅ CH ₂ CH(OH)C(C ₆ H ₅) ₂ OH	58
C₉H₉O₃-NRR'			
3,4-(CH ₃ O) ₂ C ₆ H ₃ CONH ₂	C ₂ H ₅ MgBr	3,4-(CH ₃ O) ₂ C ₆ H ₃ COC ₂ H ₅ (70%); 3,4-(CH ₃ O) ₂ C ₆ H ₃ Cl (= NH)C ₂ H ₅	14
3,4-(CH ₃ O) ₂ C ₆ H ₃ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr (ca. 2 equiv.)	3,4-(CH ₃ O) ₂ C ₆ H ₃ COC ₂ H ₅ (70%)	15,14
3,5-(CH ₃ O) ₂ C ₆ H ₃ CONH ₂ (110 g.)	CH ₃ MgI (5-fold excess)	3,5-(CH ₃ O) ₂ C ₆ H ₃ COCH ₃ (63 g., 57%)	92
3,5-(CH ₃ O) ₂ C ₆ H ₃ CONH ₂ (0.25 mole)	C ₂ H ₅ MgBr (1 mole C ₂ H ₅ Br)	3,5-(CH ₃ O) ₂ C ₆ H ₃ COC ₂ H ₅ (84%)	78
3,5-(CH ₃ O) ₂ C ₆ H ₃ CONH ₂ (46 g.)	<i>n</i> -C ₃ H ₇ MgBr (123 g. C ₃ H ₇ Br)	3,5-(CH ₃ O) ₂ C ₆ H ₃ CO- <i>n</i> -C ₃ H ₇ (88%)	78
3,5-(CH ₃ O) ₂ C ₆ H ₃ CONH ₂	<i>n</i> -C ₄ H ₉ MgBr (4 equiv.)	3,5-(CH ₃ O) ₂ C ₆ H ₃ CO- <i>n</i> -C ₄ H ₉ (80%)	78
3,5-(CH ₃ O) ₂ C ₆ H ₃ CONH ₂	<i>n</i> -C ₅ H ₁₁ MgBr (4 equiv.)	3,5-(CH ₃ O) ₂ C ₆ H ₃ CO- <i>n</i> -C ₅ H ₁₁ (88%)	78
3,5-(CH ₃ O) ₂ C ₆ H ₃ CONH ₂	<i>n</i> -C ₆ H ₁₃ MgBr (4 equiv.)	3,5-(CH ₃ O) ₂ C ₆ H ₃ CO- <i>n</i> -C ₆ H ₁₃ (85%)	78
3,5-(CH ₃ O) ₂ C ₆ H ₃ CON(C ₂ H ₅) ₂ (47.4 g.)	<i>n</i> -C ₄ H ₉ MgBr (31.5 g. C ₄ H ₉ Br)	Recovered amide; 3,5-(CH ₃ O) ₂ C ₆ H ₃ CO- <i>n</i> -C ₄ H ₉ (18.9 g., 43%)	78
C₉H₁₁O-NRR'			
<i>t</i> -C ₄ H ₉ CH ₂ CONH ₂	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ COCH ₂ - <i>t</i> -C ₄ H ₉ (77%)	81
<i>t</i> -C ₄ H ₉ CH ₂ CONH ₂	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₅ H ₁₁ COCH ₂ - <i>t</i> -C ₄ H ₉ (60%)	81
C₉H₁₇ON			
3,3-Diethyl-5-methyl-2-pyrrolidone	RMgX	"Did not react"	67

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₆O₂N₂ Proline anhydride*	C ₆ H ₅ MgBr	1-(α -Pyrrolidyl)diphenylmethyl)- 2-benzoylpyrrolidine	91
C₁₀H₉O₂N <i>N</i> -Ethylisatin	<i>n</i> -C ₄ H ₉ MgBr (4 equiv.)	1-Ethyl-2,3-di- <i>n</i> -butyl-2,3-epoxyindoline	90
<i>N</i> -Ethylisatin	C ₆ H ₅ MgBr (5 equiv.)	1-Ethyl-2,3-diphenyl-2,3-epoxyindoline (56%); 1-methyl-3,3-diphenyloxindole (16%)	89
C₁₀H₁₀ON₂ 1,2-Dimethyl-4(1 <i>H</i>)-quinazolone (8.0 g.)	C ₆ H ₅ MgBr (17.5 g. C ₆ H ₅ Br)	Product isolated after treatment with HI as 2-methyl-4-phenylquinazolinium methiodide	21
C₁₀H₁₁O-NRR' C ₂ H ₅ CH(C ₆ H ₅)CONH ₂	<i>n</i> -C ₄ H ₉ MgBr (4 equiv.)	<i>n</i> -C ₄ H ₉ COCH(C ₂ H ₅)C ₆ H ₅	34
C ₂ H ₅ CH(C ₆ H ₅)CONH ₂	<i>i</i> -C ₄ H ₉ MgBr (4 equiv.)	<i>i</i> -C ₄ H ₉ COCH(C ₂ H ₅)C ₆ H ₅	34
C ₂ H ₅ CH(C ₆ H ₅)CONH ₂	C ₆ H ₅ CH ₂ MgCl (4 equiv.)	C ₆ H ₅ CH ₂ COCH(C ₂ H ₅)C ₆ H ₅	34
C ₂ H ₅ CH(C ₆ H ₅)CONH ₂	C ₆ H ₅ (CH ₂) ₂ MgBr (4 equiv.)	C ₆ H ₅ CH ₂ CH ₂ COCH(C ₂ H ₅)C ₆ H ₅	34
C ₆ H ₅ (CH ₃) ₂ CCONH ₂ (0.1 mole)	4-CH ₃ OC ₆ H ₄ MgBr (2.5 equiv.)	C ₆ H ₅ (CH ₃) ₂ CC(=NH·HBr)C ₆ H ₄ -4-OCH ₃ (ca. 40%)	10,8
C₁₀H₁₁O₃-NRR' 2-CH ₃ -3,5-(CH ₃ O) ₂ C ₆ H ₂ CONH ₂	CH ₃ MgBr	CH ₃ COC ₆ H ₂ -2-CH ₃ -3,5-(OCH ₃) ₂	16
C₁₀H₁₁O₄-NRR' 3,4,5-(CH ₃ O) ₃ C ₆ H ₂ CONH ₂ (90 g.)	C ₂ H ₅ MgBr (144 g. C ₂ H ₅ Br)	C ₂ H ₅ C(=NH)C ₆ H ₂ -3,4,5-(OCH ₃) ₃ (17 g.); C ₂ H ₅ COC ₆ H ₂ -3,4,5-(OCH ₃) ₃ (32 g.); recovered amide (30 g.)	15,14

* Hexahydropyrocoll.

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₁O₄NRR' (<i>cont.</i>)			
3,4,5-(CH ₃) ₃ C ₆ H ₂ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr (<i>ca.</i> 2 equiv.)	C ₂ H ₅ COC ₆ H ₂ -3,4,5-(OCH ₃) ₂ (80%)	15,14
C₁₀H₁₂O₂N-NRR'			
4-(CH ₃) ₂ NC ₆ H ₄ CH(OH)CONH ₂ (3 g.)	4-ClC ₆ H ₄ MgBr (15 g. C ₆ H ₄ BrCl)	α -4-ClC ₆ H ₄ COCH(OH)C ₆ H ₄ -4-N(CH ₃) ₂ (2 g.)	23
C₁₀H₁₆O₂-(NRR')₂			
[—(CH ₂) ₄ CON(C ₂ H ₅) ₂] ₂	C ₂ H ₅ MgBr	[—(CH ₂) ₄ COC ₂ H ₅] ₂ ; C ₂ H ₅ CO(CH ₂) ₈ COC ₂ H ₅	93
C₁₁H₉O₅-NRR'			
3,4-(CH ₃ CO) ₂ C ₆ H ₃ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr (<i>excess</i>)	CH ₃ (C ₂ H ₅) ₂ COH	15,13
C₁₁H₁₃O-NRR'			
C ₂ H ₅ CH(C ₆ H ₅)CH ₂ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr	Quant. recovery of amide	45
C ₆ H ₅ CH(<i>n</i> -C ₃ H ₇)CONH ₂	<i>i</i> -C ₄ H ₉ MgBr (4 equiv.)	<i>i</i> -C ₄ H ₉ COCH(<i>n</i> -C ₃ H ₇)C ₆ H ₅	34
C ₆ H ₅ CH(<i>i</i> -C ₃ H ₇)CONH ₂	<i>n</i> -C ₄ H ₉ MgBr (4 equiv.)	<i>n</i> -C ₄ H ₉ COCH(<i>i</i> -C ₃ H ₇)C ₆ H ₅	34
C ₆ H ₅ CH ₂ (CH ₃) ₂ CCONH ₂	C ₂ H ₅ MgBr (3 equiv.)	C ₂ H ₅ COC(CH ₃) ₂ CH ₂ C ₆ H ₅	68
C ₆ H ₅ CH ₂ (CH ₃) ₂ CCONH ₂	C ₆ H ₅ MgBr (3 equiv.)	C ₆ H ₅ COC(CH ₃) ₂ CH ₂ C ₆ H ₅ ; C ₆ H ₅ CH ₂ (CH ₃) ₂ CCN	68
CH ₃ (C ₂ H ₅)(C ₆ H ₅)CCONH ₂	C ₆ H ₅ MgBr (3 equiv.)	CH ₃ (C ₂ H ₅)(C ₆ H ₅)CCN	68
C₁₂H₉O₃-NRR'			
2-CH ₃ OC ₁₀ H ₆ -3-CONH ₂	CH ₃ MgI	2-CH ₃ OC ₁₀ H ₆ -3-CN	19
C₁₂H₁₃ON			
1-Methyl-5-benzyl-2(3 <i>H</i>)-pyrrolone	CH ₃ MgBr	1,2-Dimethyl-5-benzylpyrrole (19%); 1,5,5-trimethyl-2-benzyl- Δ^2 -pyrroline	36

TABLE XII-I (Continued)

Co-reactant	RMgX	Product(s)	Ref.
C₁₂H₁₃ON (<i>cont.</i>)			
1-Methyl-5-benzyl-2(3 <i>H</i>)-pyrrolone	C ₂ H ₅ MgBr	1-Methyl-2-ethyl-5-benzylpyrrole (50%)	36
1-Methyl-5-benzyl-2(3 <i>H</i>)-pyrrolone	C ₆ H ₅ CH ₂ MgCl	1-Methyl-2,5-dibenzylpyrrole	36
C₁₂H₁₅O-NRR'			
C ₆ H ₅ CH(<i>n</i> -C ₄ H ₉)CONH ₂	C ₂ H ₅ MgBr (4 equiv.)	C ₂ H ₅ COCH(<i>n</i> -C ₄ H ₉)C ₆ H ₅	34
C ₆ H ₅ CH(<i>n</i> -C ₄ H ₉)CONH ₂	<i>n</i> -C ₃ H ₇ MgBr (4 equiv.)	<i>n</i> -C ₃ H ₇ COCH(<i>n</i> -C ₄ H ₉)C ₆ H ₅	34
C ₆ H ₅ CH(<i>i</i> -C ₄ H ₉)CONH ₂	<i>n</i> -C ₃ H ₇ MgBr (4 equiv.)	<i>n</i> -C ₃ H ₇ COCH(<i>i</i> -C ₄ H ₉)C ₆ H ₅	34
C ₆ H ₅ (C ₂ H ₅) ₂ CCONH ₂	C ₆ H ₅ MgBr (3 equiv.)	C ₆ H ₅ (C ₂ H ₅) ₂ CCN	68
C₁₃H₉O₂-NRR'			
(C ₄ H ₃ O)CH = C(C ₆ H ₅)CON(C ₂ H ₅) ₂ * (30 g.)	C ₂ H ₅ MgBr (37 g. C ₂ H ₅ Br)	C ₂ H ₅ (C ₄ H ₃ O)CHCH(C ₆ H ₅)CON(C ₂ H ₅) ₂ * (27 g.)	54
(C ₄ H ₃ O)CH = C(C ₆ H ₅)CON(C ₂ H ₅) ₂ * (30 g.)	C ₆ H ₅ MgBr (53 g. C ₆ H ₅ Br)	C ₆ H ₅ (C ₄ H ₃ O)CHCH(C ₆ H ₅) ₂ CON(C ₂ H ₅) ₂ * (29 g.)	54
(C ₄ H ₃ O)CH = C(C ₆ H ₅)CON(CH ₃)C ₆ H ₅ * (30.0 g.)	C ₂ H ₅ MgBr (30.5 g. C ₂ H ₅ Br)	C ₂ H ₅ (C ₄ H ₃ O)CHCH(C ₆ H ₅)CON(CH ₃)C ₆ H ₅ * (28.0 g.)	54
(C ₄ H ₃ O)CH = C(C ₆ H ₅)CON(CH ₃)C ₆ H ₅ * (30 g.)	C ₆ H ₅ MgBr (44 g. C ₆ H ₅ Br)	C ₆ H ₅ (C ₄ H ₃ O)CHCH(C ₆ H ₅)CON(CH ₃)C ₆ H ₅ * (28.0 g.)	54
(C ₄ H ₃ O)CH = C(C ₆ H ₅)CON(C ₆ H ₅) ₂ * (20.0 g.)	C ₂ H ₅ MgBr (14.5 g. C ₂ H ₅ Br)	C ₂ H ₅ (C ₄ H ₃ O)CHCH(C ₆ H ₅)CON(C ₆ H ₅) ₂ * (18.0 g.)	54
(C ₄ H ₃ O)CH = C(C ₆ H ₅)CON(C ₆ H ₅) ₂ * (20 g.)	C ₆ H ₅ MgBr (19 g. C ₆ H ₅ Br)	C ₆ H ₅ (C ₄ H ₃ O)CHCH(C ₆ H ₅)CON(C ₆ H ₅) ₂ * (19 g.)	54
C₁₃H₁₁O₇-NRR'			
3,4,5-(CH ₃ CO ₂) ₃ C ₆ H ₂ CON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr (excess)	CH ₃ (C ₂ H ₅) ₂ COH	15,13
C₁₄H₈ON₂Cl			
3- <i>p</i> -Chlorophenyl-4(3 <i>H</i>)-quinazolone	C ₆ H ₅ CH ₂ MgCl (2-3 equiv.)	2-(C ₆ H ₅ CH ₂) ₂ CHNHC ₆ H ₄ CONHC ₆ H ₄ -4-Cl	31

* (C₄H₃O) = α -furyl.

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₉ON₂ 3-Phenyl-4(3 <i>H</i>)-quinazolone (20 g.).	C ₆ H ₅ CH ₂ MgCl (2-3 equiv.)	2-(C ₆ H ₅ CH ₂) ₂ CHNHC ₆ H ₄ CONHC ₆ H ₅ (34.5 g., 94% crude)	31
C₁₄H₁₁O-NRR' (C ₆ H ₅) ₂ CHCONH ₂ (15 g.) (C ₆ H ₅) ₂ CHCONH ₂ (20 g.) (C ₆ H ₅) ₂ CHCON(C ₂ H ₅) ₂	C ₂ H ₅ MgBr (30 g. C ₂ H ₅ Br) C ₆ H ₅ MgBr (52 g. C ₆ H ₅ Br) RMgBr*	C ₂ H ₅ COCH(C ₆ H ₅) ₂ (11 g., 31%) C ₆ H ₅ COCH(C ₆ H ₅) ₂ (11 g., 42%) No reaction	45,43 45 45,43
C₁₄H₁₁O₂-NRR' (C ₆ H ₅) ₂ C(OH)CONH ₂ (C ₆ H ₅) ₂ C(OH)CONH ₂ (4.5 g.) 2-Methyl-3-phenyl-4(3 <i>H</i>)-quinazolone (3.0 g.) 2-Methyl-3-phenyl-4(3 <i>H</i>)-quinazolone (3.0 g.) 2-Methyl-3-phenyl-4(3 <i>H</i>)-quinazolone (0.05 mole)	4-CH ₃ C ₆ H ₄ MgI 4-CH ₃ C ₆ H ₄ MgI (26.2 g. C ₆ H ₄ ICl) <i>n</i> -C ₃ H ₇ MgBr (1.6 g. C ₃ H ₇ Br) <i>n</i> -C ₄ H ₉ MgBr (1.6 g. C ₄ H ₉ Br) C ₆ H ₅ MgBr (0.05 mole)	Amide recovered unchanged† (C ₆ H ₅) ₂ CHCONH ₂ (1.5 g.)‡ 2-Methyl-3-phenyl-4- <i>n</i> -propyl-3,4- dihydro-4-quinazolinol (2.5 g.) 2-Methyl-3-phenyl-4- <i>n</i> -butyl-3,4- dihydro-4-quinazolinol (2.5 g.) 2-Methyl-3,4-diphenyl-3,4-dihydro- 4-quinazolinol (7.5 g.)	11 11 94 94 94
C₁₅H₁₃O-NRR' (C ₆ H ₅) ₂ CHCH ₂ CON(C ₂ H ₅) ₂	RMgX	No reaction	45
C₁₅H₂₆O₂-NR <i>N</i> , α-Dimethyl-α- <i>n</i> -decylsuccinimide (20 g.)	<i>n</i> -C ₁₀ H ₂₁ MgBr (35 g. C ₁₀ H ₂₁ Br)	1,3-Dimethyl-3,5-di- <i>n</i> -decyl-2(3 <i>H</i>)- pyrrolone (8 g., crude)	3

* R = C₂H₅, C₆H₅.† Eight hours reflux in Et₂O.‡ Eight hours reflux in *n*-Am₂O.

TABLE XII-I (Continued)

<u>Co-reactant</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₁₅O-NRR'			
C ₆ H ₅ CH ₂ CH ₂ CH(C ₆ H ₅)CONH ₂	C ₂ H ₅ MgBr (4 equiv.)	C ₂ H ₅ COCH(C ₆ H ₅)CH ₂ CH ₂ C ₆ H ₅	34
(C ₆ H ₅ CH ₂) ₂ CHCONH ₂ (10 g.)	C ₂ H ₅ MgBr (25 g. C ₂ H ₅ Br)	C ₂ H ₅ COCH(CH ₂ C ₆ H ₅) ₂ (3.5 g., 32%)	45,43
(C ₆ H ₅ CH ₂) ₂ CHCON(C ₂ H ₅) ₂	RMgBr*	No reaction	45,43
C₂₁H₁₇O-NRR'			
C ₆ H ₅ CH ₂ (C ₆ H ₅) ₂ CCONH ₂	C ₆ H ₅ MgBr (3 equiv.)	C ₆ H ₅ CH ₂ (C ₆ H ₅) ₂ CCN	68
<i>N,N'</i> -Bis-(<i>p</i> -tolylsulfonyl)- dianthranilide	CH ₃ MgI	α,α -Dimethyl-2-(<i>p</i> -tolylsulfonylamido)- benzyl alcohol	95
<i>N,N'</i> -Bis-(<i>p</i> -tolylsulfonyl)- dianthranilide	C ₆ H ₅ MgBr	α,α -Diphenyl-2-(<i>p</i> -tolylsulfonylamido)- benzyl alcohol	95
<i>N,N'</i> -Bis-(<i>p</i> -tolylsulfonyl)- dianthranilide	4-CH ₃ C ₆ H ₄ MgBr	α,α -Di- <i>p</i> -tolyl-2-(<i>p</i> -tolylsulfonylamido)benzyl alcohol	95

* R = C₂H₅, C₆H₅.

REFERENCES FOR TABLE XII-I

- (1) Barré, *Ann. chim.*, [10], 9, 204-75 (1927).
- (2) Béis, *Compt. rend.*, 137, 575-6 (1930); *Chem. Zentr.*, 1903,II, 1110.
- (3) Birch and Robinson, *J. Chem. Soc.*, 1942, 488-97.
- (4) Blaise, *Compt. rend.*, 173, 313-5 (1921).
- (5) Blaise and Montagne, *Compt. rend.*, 180, 1345-6 (1925).
- (6) Bouveault, *Compt. rend.*, 137, 987-9 (1903); *Chem. Zentr.*, 1904,I, 257.
- (7) Bouveault, *Bull. soc. chim.*, [3], 31, 1322-7 (1904).
- (8) Bruzau, *Compt. rend.*, 194, 1662-4 (1932).
- (9) Bruzau, *Compt. rend.*, 196, 122-4 (1932).
- (10) Bruzau, *Ann. chim.*, [11], 1, 257-358 (1934).
- (11) Burton, *J. Chem. Soc.*, 1930, 2400.
- (12) Busch and Fleischmann, *Ber.*, 43, 2553-6 (1910).
- (13) Couturier, *Compt. rend.*, 202, 1994-6 (1936); *Chem. Abstr.*, 30, 6725 (1936).
- (14) Couturier, *Compt. rend.*, 205, 800-2 (1937); *Chem. Abstr.*, 32, 1251 (1938).
- (15) Couturier, *Ann. chim.*, [11], 10, 559-629 (1938).
- (16) Cram, *J. Am. Chem. Soc.*, 70, 440-1 (1948).
- (17) Darmon, *Compt. rend.*, 197, 1328-9 (1933).
- (18) Ellingboe and Fuson, *J. Am. Chem. Soc.*, 56, 1777-9 (1934).
- (19) Fries and Schimmelschmidt, *Ber.*, 58B, 2835-45 (1925).
- (20) Grammaticakis, *Compt. rend.*, 207, 239-41 (1938); *Chem. Abstr.*, 34, 2808 (1940).
- (21) Hamer, Heilbron, Reade, and Walls, *J. Chem. Soc.*, 1932, 251-60.
- (22) Houben and Doescher, *Ber.*, 40, 4576-9 (1907).
- (23) Jenkins, *J. Am. Chem. Soc.*, 53, 3115-22 (1931).
- (24) Jenkins, *J. Am. Chem. Soc.*, 54, 1155-63 (1932).
- (25) Jenkins, *J. Am. Chem. Soc.*, 55, 703-6 (1933).
- (26) Jenkins, *J. Am. Chem. Soc.*, 55, 2896-9 (1933).
- (27) Jenkins, *J. Am. Chem. Soc.*, 56, 682-4 (1934).
- (28) Jenkins, *J. Am. Chem. Soc.*, 56, 1137-8 (1934).
- (29) Jenkins and Richardson, *J. Am. Chem. Soc.*, 55, 1618-21 (1933).
- (30) Jenkins and Richardson, *J. Am. Chem. Soc.*, 55, 3874-9 (1933).
- (31) Koelsch, *J. Am. Chem. Soc.*, 67, 1718-20 (1945).
- (32) Kohler and Heritage, *Am. Chem. J.*, 33, 21-35 (1905).
- (33) Kroegeer and Nieuwland, *J. Am. Chem. Soc.*, 58, 1861-3 (1936).
- (34) Lévy and Jullien, *Bull. soc. chim.*, [4], 45, 941-50 (1929).
- (35) Lukeš, *Collection Czechoslov. Chem. Commun.*, 2, 531-44 (1930); *Chem. Abstr.*, 25, 102 (1931).
- (36) Lukeš, *Collection Czechoslov. Chem. Commun.*, 4, 181-92 (1932); *Chem. Zentr.*, 1932,II, 873; *Chem. Abstr.*, 26, 4328 (1932).
- (37) Lukeš, *Collection Czechoslov. Chem. Commun.*, 5, 761-9 (1932); *Chem. Abstr.*, 27, 290 (1933).
- (38) Lukeš and Gorocholinskij, *Collection Czechoslov. Chem. Commun.*, 8, 223-35 (1936); *Chem. Abstr.*, 30, 5989 (1936).
- (39) Lukeš and Prelog, *Chem. Listy*, 22, 244-51 (1928); *Chem. Abstr.*, 23, 1408 (1929).
- (40) Lukeš and Smolek, *Collection Czechoslov. Chem. Commun.*, 7, 482-90 (1935); *Chem. Abstr.*, 30, 1785 (1936).
- (41) Lukeš and Smolek, *Collection Czechoslov. Chem. Commun.*, 11, 506-16 (1939); *Chem. Abstr.*, 34, 7868 (1940).
- (42) Lukeš, Šorm, and Arnold, *Collection Czechoslov. Chem. Commun.*, 12, 641-6 (1947); *Chem. Abstr.*, 42, 5899 (1948).
- (43) Maxim, *Compt. rend.*, 182, 1393-5 (1926).
- (44) Maxim, *Bull. soc. chim.*, [4], 41, 809-13 (1927).

- (45) Maxim, *Ann. chim.*, [10], 9, 55-111 (1928).
- (46) Maxim, *Bul. soc. chim. România*, 10, 97-115 (1928); *Chem. Zentr.*, 1929, I, 2161.
- (47) Maxim, *Bul. soc. chim. România*, 11, 123-9 (1929); *Chem. Zentr.*, 1930, I, 2550.
- (48) Maxim, *Bul. soc. chim. România*, 12, 33-5 (1930); *Chem. Zentr.*, 1930, II, 3023.
- (49) Maxim and Andreescu, *Bull. soc. chim.*, [5], 5, 54-7 (1938).
- (50) Maxim and Ioanid, *Bul. soc. chim. România*, 10, 29-48 (1928); *Chem. Zentr.*, 1928, II, 754.
- (51) Maxim and Ioanid, *Bul. soc. chim. România*, 12, 28-32 (1930); *Chem. Zentr.*, 1930, II, 3013.
- (52) Maxim and Mavrodineanu, *Bull. soc. chim.*, [5], 2, 591-600 (1935).
- (53) Maxim and Mavrodineanu, *Bull. soc. chim.*, [5], 3, 1084-93 (1936).
- (54) Maxim and Stancovici, *Bull. soc. chim.*, [5], 3, 1319-23 (1936).
- (55) Maxim and Zugrăvescu, *Bull. soc. chim.*, [5], 1, 1087-99 (1934).
- (56) Maxim, Zugrăvescu, and Fulga, *Bull. soc. chim.*, [5], 6, 1339-47 (1939).
- (57) McKenzie and Duff, *Ber.*, 60B, 1335-41 (1927).
- (58) McKenzie, Martin, and Rule, *J. Chem. Soc.*, 105, 1583-91 (1914).
- (59) Montagne, *Compt. rend.*, 183, 216-8 (1926).
- (60) Montagne and Guilmart, *Bull. soc. chim.*, [5], 12, 836-9 (1945).
- (61) Montagne and Isambert, *Compt. rend.*, 203, 331-3 (1936); *Chem. Abstr.*, 30, 8210 (1936).
- (62) Montagne and Isambert, *Compt. rend.*, 208, 285-7 (1939); *Chem. Abstr.*, 33, 3772 (1939).
- (63) Montagne and Rousseau, *Compt. rend.*, 196, 1165-7 (1933).
- (64) Nenitzescu, *Bul. soc. chim. România*, 12, 48-57 (1930); *Chem. Zentr.*, 1930, II, 3014.
- (65) Nenitzescu and Cantuniari, *Bul. soc. chim. România*, 14, 62-4 (1932); *Chem. Abstr.*, 27, 958 (1933).
- (66) Nicolle, *Bull. soc. chim.*, [4], 39, 55-67 (1926).
- (67) Ramart-Lucas and Fasal, *Compt. rend.*, 184, 1253-5 (1927); *Chem. Abstr.*, 21, 2472 (1927).
- (68) Ramart-Lucas, Laclôtre, and Anagnostopoulos, *Compt. rend.*, 185, 282-4 (1927).
- (69) Roger, *Helv. Chim. Acta*, 12, 1060-7 (1929).
- (70) Sachs and Ludwig, *Ber.*, 37, 385-90 (1904).
- (71) Sachs, von Wolff, and Ludwig, *Ber.*, 37, 3252-68 (1904).
- (72) Sanna, *Gazz. chim. ital.*, 64, 857-60 (1934); *Chem. Abstr.*, 29, 3336 (1935).
- (73) Skraup and Moser, *Ber.*, 55B, 1080-101 (1922).
- (74) Smith, *Ber.*, 71B, 634-43 (1938).
- (75) Smith and Bayliss, *J. Org. Chem.*, 6, 437-42 (1941).
- (76) Sou Phou Ti, *Compt. rend.*, 192, 1462-4 (1931).
- (77) Sou Phou Ti, *Bull. faculté sci. univ. franco-chinoise, Peiping*, No. 1, 1-40 (1934); *Chem. Abstr.*, 29, 2519 (1935).
- (78) Suter and Weston, *J. Am. Chem. Soc.*, 61, 232-6 (1939).
- (79) Tiffeneau and Lévy, *Bull. soc. chim.*, [4], 37, 1247-51 (1925).
- (80) Tschugaeff, *Ber.*, 40, 186-7 (1907).
- (81) Whitmore, Popkin, Whitaker, Mattil, and Zech, *J. Am. Chem. Soc.*, 60, 2462-4 (1938).
- (82) Whitmore and Sloat, *J. Am. Chem. Soc.*, 64, 2968-70 (1942).
- (83) Wohl and Lange, *Ber.*, 41, 3612-20 (1908).
- (84) Wren, *J. Chem. Soc.*, 95, 1583-93 (1909).
- (85) Zaher and Faseeh, *J. Indian Chem. Soc.*, 21, 381-2 (1944).

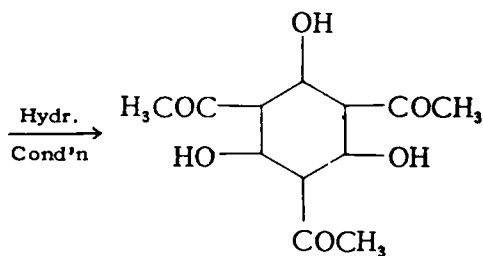
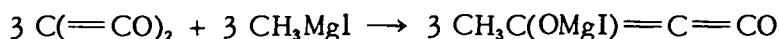
- (86) Viguiier, *Compt. rend.*, 153, 955-7 (1911); *Chem. Zentr.*, 1912,1, 20.
- (87) Sou Phou Ti, *Bull. soc. chim.*, [5], 2, 1799-800 (1935).
- (88) Adams, Bramlet, and Tendick, *J. Am. Chem. Soc.*, 42, 2369-74 (1920).
- (89) Meyers and Lindwall, *J. Am. Chem. Soc.*, 60, 2153-5 (1938).
- (90) Sumpter, *Trans. Kentucky Acad. Sci.*, 9, 61-4 (1941); *Chem. Abstr.*, 36, 4508 (1942).
- (91) Kapfhammer and Matthes, *Z. physiol. Chem.*, 223, 43-52 (1933); *Chem. Abstr.*, 28, 2353 (1934); *Chem. Zentr.*, 1934,1, 2759.
- (92) Adams, Harfenist, and Loewe, *J. Am. Chem. Soc.*, 71, 1624-8 (1949).
- (93) Paraskova, *Compt. rend.*, 198, 1701-3 (1934).
- (94) Sen and Sidhu, *J. Indian Chem. Soc.*, 25, 437-8 (1948); *Chem. Abstr.*, 43, 4675 (1949).
- (95) Mustafa and Gad, *J. Chem. Soc.*, 1949, 384-7.

CHAPTER XIII

Reactions of Grignard Reagents with Oxides of Carbon, and with Carboxylic Acids and Their Salts.

CARBON SUBOXIDE

Carbon suboxide (C_3O_2) is essentially a bifunctional ketene. Its reaction with methylmagnesium iodide has been investigated by Billman and Smith.¹ Under the experimental conditions employed by them (addition of ethereal suboxide solution to ice-salt-cooled Grignard reagent solution to negative Grignard reagent test²) each molecule of suboxide reacts with only one molecule of Grignard reagent—probably because of the ether-insolubility of the initial product. The product isolated (in 24 percent yield) was 2,4,6-triacetylphloroglucinol. The reaction, therefore, may be represented as follows:



According to a private communication to Billman and Smith (*loc. cit.*¹, footnote, p. 458), Reyerson and Kolbe have obtained an unidentified white product from the interaction of carbon suboxide and phenylmagnesium bromide.

More recently Billman and Smith^{2,1} have reëxamined the reaction of methylmagnesium iodide with carbon suboxide, and have isolated, in addition to the major product (triacetylphloroglucinol), a small amount of dehydroacetic acid (2-acetyl-3-oxo-5-hydroxy-4-hexenoic acid δ -lactone).

From cyclohexylmagnesium bromide and carbon suboxide they have obtained the 2,4,6-triacetylphloroglucinol derivative analogous to the methylmagnesium iodide product.

¹ Billman and Smith, *J. Am. Chem. Soc.*, 61, 457-8 (1939).

² Gilman and Schulze, *J. Am. Chem. Soc.*, 47, 2002-5 (1925).

^{2,1} Billman and Smith, *J. Am. Chem. Soc.*, 74, 3174 (1952).

CARBON MONOXIDE

In his first general review of work on organomagnesium halides and their reactions, Grignard³ remarked that carbon monoxide is at once an unsaturated compound and a carbonyl group,* and that, if it were possible to arrest reaction at the first stage, the oxide might be expected to combine with organomagnesium halides to form aldehyde derivatives.



He added that unpublished experiments of his own indicated that at ordinary temperatures reaction proceeds through a second stage, yielding secondary alcohols. To the knowledge of the present authors, Grignard published no account of these experiments, and made no further published reference to the subject.

Vinay⁴ claimed to have obtained tertiary alcohols from the interaction of carbon monoxide and Grignard reagents of the types R_2CHMgX and R_3CMgX .

Jegorowa⁵ reported that carbon monoxide reacts with isopropylmagnesium bromide to yield 2,4-dimethyl-2-pentene $[(\text{CH}_3)_2\text{C}=\text{CH}-i\text{-C}_3\text{H}_7]$ and 2,3,4-trihydroxy-2,3,4-triisopropyl-5-oxo-6-methylheptanal $\{i\text{-C}_3\text{H}_7\text{CO}[\text{C}(\text{OH})-i\text{-C}_3\text{H}_7]_3\text{CHO}\}$; that it reacts with *t*-butylmagnesium chloride to form 2,2,5,5-tetramethyl-4-hydroxy-3-hexanone $[t\text{-C}_4\text{H}_9\text{COCH}(\text{OH})\text{-}t\text{-C}_4\text{H}_9]$; and that from its interaction with *t*-amylmagnesium chloride only ethyldimethylcarbinol $[\text{C}_2\text{H}_5(\text{CH}_3)_2\text{COH}]$ was obtained. No reaction took place, however, between carbon monoxide and methylmagnesium iodide, phenylmagnesium bromide, *t*-heptylmagnesium bromide, or triphenylmethylmagnesium chloride.

Eidus *et al.*⁶ report that carbon monoxide under pressure reacts with *n*-butylmagnesium bromide to yield 4-nonene (25.4 percent), with *n*-butylmagnesium chloride to yield 4-nonene (51.0 percent), with isoämylmagnesium bromide to yield 2,8-dimethyl-4-nonene (51.0 percent), and with isoämylmagnesium chloride to yield 2,8-dimethyl-4-nonene (53.6 percent).

In a private communication to Schlubach,⁷ Staudinger stated that carbon monoxide either does not react with phenylmagnesium bromide, or reacts to form complicated products.

³ Grignard, *Bull. soc. chim.*, [4], 13, I-XXXVII (1926).

* In the light of present-day valence theories the fallacy of this line of reasoning is, of course, obvious.

⁴ Vinay, Dissertation, Geneva, 1913, as cited by: Gilliland and Blanchard, *J. Am. Chem. Soc.*, 48, 410-20 (1926); Fischer and Stoffers, *Ann.*, 500, 253-70 (1933).

⁵ Jegorowa, *J. Russ. Phys.-Chem. Soc.*, 46, 1319-32 (1914); *Chem. Zentr.*, 1915, I, 1055.

⁶ Eidus, Elagina, and Zelinski, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1945, 672-4; *Chem. Abstr.*, 42, 5838 (1948).

⁷ Schlubach, *Ber.*, 52B, 1910-4 (1919).

Zelinsky⁸ has reported the formation of aldehydes and ketones by the action of nickel carbonyl on *n*-propylmagnesium iodide. From alkylmagnesium iodides and nickel carbonyl Jones⁹ obtained dark oils from which no identified products were isolated, but from the products of reaction of phenylmagnesium iodide and nickel carbonyl he was able to isolate biphenyl and benzoïn.

Gilliland and Blanchard¹⁰ found that the finely divided nickel liberated when nickel carbonyl reacts with phenylmagnesium bromide in ethereal solution regenerates nickel carbonyl when carbon monoxide is passed into the suspension. A similar observation had been made previously by Job and Reich¹¹ regarding nickel liberated in the reaction of nickel chloride (NiCl_2) with Grignard reagents.

Gilliland and Blanchard accordingly investigated the reaction initiated by adding a small quantity of nickel carbonyl to an ethereal solution of phenylmagnesium bromide, and continued by passing carbon monoxide into the reaction mixture. From the reaction products they were able to isolate triphenylmethane, triphenylvinyl alcohol, small amounts of pentaphenylethane, and, occasionally, small amounts of tetraphenylethylene. When the experimental conditions were such that carbon monoxide absorption was slow, triphenylmethane was the predominant product; when carbon monoxide absorption was rapid triphenylvinyl alcohol predominated. The foregoing products are all soluble in ether. A red crystalline product which deposited during the course of the reaction was partially identified as an etherated basic magnesium bromide.

Gilliland and Blanchard accounted for the products identified by the following series of reactions:

- (1) $\text{>CO} + \text{C}_6\text{H}_5\text{MgBr} \rightarrow \text{C}_6\text{H}_5\text{COMgBr}$
- (2) $\text{C}_6\text{H}_5\text{COMgBr} + \text{C}_6\text{H}_5\text{MgBr} \rightarrow (\text{C}_6\text{H}_5)_2\text{C(OMgBr)MgBr}$
- (3) $(\text{C}_6\text{H}_5)_2\text{C(OMgBr)MgBr} + \text{C}_6\text{H}_5\text{MgBr} \rightarrow (\text{C}_6\text{H}_5)_3\text{CMgBr} + (\text{BrMg})_2\text{O}$
- (4) $(\text{C}_6\text{H}_5)_2\text{C(OMgBr)MgBr} + \text{>CO} \rightarrow \text{BrMgO(C}_6\text{H}_5)_2\text{CCOMgBr}$
- (5) $\text{BrMgO(C}_6\text{H}_5)_2\text{CCOMgBr} \rightarrow (\text{C}_6\text{H}_5)_2\text{C}=\text{C}=\text{O} + (\text{BrMg})_2\text{O}$
- (6) $(\text{C}_6\text{H}_5)_2\text{C}=\text{C}=\text{O} + \text{C}_6\text{H}_5\text{MgBr} \rightarrow (\text{C}_6\text{H}_5)_2\text{C}=\text{C(C}_6\text{H}_5\text{)OMgBr}$
- (7) $(\text{C}_6\text{H}_5)_3\text{CMgBr} + \text{>CO} \rightarrow (\text{C}_6\text{H}_5)_3\text{CCOMgBr}$
- (8) $(\text{C}_6\text{H}_5)_3\text{CCOMgBr} + \text{C}_6\text{H}_5\text{MgBr} \rightarrow (\text{C}_6\text{H}_5)_3\text{CC(C}_6\text{H}_5\text{)(OMgBr)MgBr}$
- (9) $(\text{C}_6\text{H}_5)_3\text{CC(C}_6\text{H}_5\text{)(OMgBr)MgBr} + \text{C}_6\text{H}_5\text{MgBr} \rightarrow$
 $(\text{C}_6\text{H}_5)_3\text{CC(C}_6\text{H}_5)_2\text{MgBr} + (\text{BrMg})_2\text{O}$

⁸ Zelinsky, *J. Russ. Phys.-Chem. Soc.*, 36, 339-40 (1904); as cited by Gilliland and Blanchard, *J. Am. Chem. Soc.*, 48, 410-20 (1926).

⁹ Jones, *Chem. News*, 90, 144-5 (1904).

¹⁰ Gilliland and Blanchard, *J. Am. Chem. Soc.*, 48, 410-20 (1926).

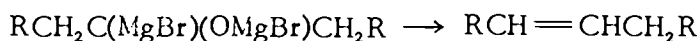
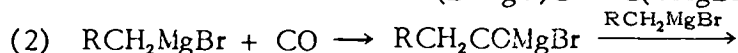
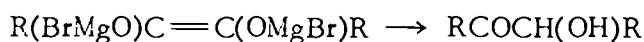
¹¹ Job and Reich, *Compt. rend.*, 177, 1438-41 (1923); *Chem. Abstr.*, 19, 1851 (1925).

Job and Cassal¹² report that when small quantities of chromium chloride (CrCl_3) are added to an ethereal solution of phenylmagnesium bromide the resultant reaction system absorbs carbon monoxide more or less rapidly at temperatures between -15° and the boiling point of ether. (The lower temperature is that at which reaction between chromium chloride and the Grignard reagent begins.) The reaction products isolated and identified were: biphenyl, benzophenone, benzhydrol, triphenylvinyl alcohol, β -benzopinacolone, benzoïn, benzil, and triphenylmethane, together with traces of benzaldehyde, phenol, and chromium carbonyl. Roughly 50 percent of the Grignard reagent expended is thus accounted for; the remainder gives rise to resinous or tarry materials.

Job and Cassal attribute the chromium chloride activation of the carbon monoxide-phenylmagnesium bromide reaction to the formation of an intermediate chromium carbonyl compound or compounds. Chromium carbonyl itself appears to be ineffective.

The work of Fischer and Stoffers¹³ raises the question whether or not there are in fact any uncatalyzed reactions of carbon monoxide with Grignard reagents. Operating in an autoclave under carbon monoxide pressures from 50 up to 180 atmospheres and at temperatures from 60° to as high as 160° , they found that carbon monoxide absorption begins at much lower temperatures and proceeds much more rapidly when small amounts of halomagnesium alcoholates (generated either by oxidation of the Grignard reagent or by addition of alcohol) are present in the system. It was found that the alcoholates do not themselves react with carbon monoxide, although they do, in some way, facilitate the Grignard reaction.

Two types of reactions were observed: (1) that characteristic for aryl- and *t*-alkylmagnesium halides, in which one molecule of carbon monoxide per molecule of Grignard reagent is absorbed; (2) that characteristic for primary alkylmagnesium halides, in which one-half molecule of carbon monoxide per molecule of Grignard reagent is absorbed. *s*-Alkylmagnesium halides undergo both types of reaction simultaneously. Fischer and Stoffers describe the two typical modes of reaction schematically as follows.



The acyloïns may be accompanied by, or even completely converted to, the corresponding "autoxidation" products (the diketones). Under the experimental conditions employed by Fischer and Stoffers, phenylmagnesium bromide yielded benzoïn (90 percent), together with small amounts

¹² Job and Cassal, *Compt. rend.*, 183, 58-60 (1926); *Chem. Abstr.*, 20, 2999 (1926); *Bull. soc. chim.*, [4], 41, 814-24 (1927).

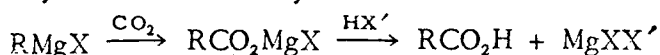
¹³ Fischer and Stoffers, *Ann.*, 500, 253-70 (1933).

of benzil; *p*-tolylmagnesium bromide behaved similarly; α -naphthylmagnesium bromide yielded only α -naphthil (63 percent); *t*-butylmagnesium bromide yielded hexamethylacetoin (2,2,5,5-tetramethyl-4-hydroxy-3-hexanone). Ethylmagnesium bromide yielded 2-pentene (25 percent); *n*-butylmagnesium chloride, 4-nonene (65 percent); isoamylmagnesium bromide, 2,8-dimethyl-4-nonene (70 percent); benzylmagnesium chloride, 1,3-diphenylpropene (60 percent). Cyclohexylmagnesium bromide yielded cyclohexylmethylenecyclohexane (25 percent), together with dodecahydrobenzoïn and dodecahydrobenzil (aggregating 44 percent).

No reaction was effected with pyrrolmagnesium bromide (100°, 90 atmospheres), *p*-dimethylaminophenylmagnesium bromide, or ethynylenedimagnesium bromide (145°, 90 atmospheres).

CARBON DIOXIDE

It was discovered by Grignard¹⁴ that when carbon dioxide is passed into an ethereal solution of an organomagnesium halide gas absorption takes place, with the formation of a carboxylate from which the corresponding carboxylic acid is readily liberated.



The principal side-reactions, also observed by Grignard,¹⁵ are successive reaction of the carboxylate thus formed with one or two molecules, respectively, of excess Grignard reagent to form ketone or tertiary alcohol. For most aliphatic Grignard reagents the relative rates of the successive reactions are such that tertiary alcohol is the principal byproduct, and little or no ketone can be isolated. For some aromatic Grignard reagents (especially those that give rise to "hindered" ketones), ketone is the principal byproduct. In most cases, however, it is possible, by suitable selection of experimental conditions, to arrest reaction at the carboxylate stage, and thus to obtain a fairly satisfactory yield of carboxylic acid.

As was demonstrated by Bodroux,¹⁶ one effective method of reaction control is operation at low temperature, which reduces both the solubility and the reactivity of the carboxylate initially formed. Bodroux found, for example, that when carbon dioxide is passed into an ethereal solution of *p*-chlorophenylmagnesium bromide at the boiling point of the solution (*ca.* 36°) the principal product is *p,p'*-dichlorobenzophenone (50 percent), the *p*-chlorobenzoic acid being obtained in only 24 percent yield. When the gas is passed into a cooled solution at 0° the yield of acid is increased

¹⁴Grignard, *Annales de l'Universite de Lyon*, N.S., 6, 1-116 (1901); *Chem. Zentr.*, 1901,II, 622; *Ann. chim.*, [7], 24, 433-90 (1901).

¹⁵Grignard, *Compt. rend.*, 138, 152-4 (1904); *Chem. Zentr.*, 1904,I, 577; *Bull. soc. chim.*, [3], 31, 751-7 (1904).

¹⁶Bodroux, (a) *Compt. rend.*, 137, 710-2 (1903); *Chem. Zentr.*, 1903,II, 1441; (b) *Bull. soc. chim.*, [3], 31, 24-30 (1904).

to 60 percent and that of the benzophenone reduced to 18 percent. When carbonation is effected by the addition of carbon dioxide snow to the reaction system at an average temperature of about -40° the yields of acid and benzophenone are 80 percent and 4 percent, respectively. Similar results were obtained with *p*-bromophenylmagnesium bromide.

Another method of control for which several procedures have been adopted is to avoid, as far as possible, the presence of excess Grignard reagent.

According to Kinney and Mayhue¹⁷ the presence of the halomagnesium alcoholate corresponding to the Grignard reagent inhibits the reaction of the Grignard reagent with carbon dioxide and lowers the yield of acid obtainable.

Preparative procedures. The principal carbonation method variations, together with their symbolic designations as employed in column 2 of Table XIII-I, are as follows.

Method I. The classical method of Grignard (*loc. cit.*¹⁴), consisting in bubbling carbon dioxide gas into a Grignard reagent solution. If desired the solution may be externally cooled, or, in special cases, heated.

Method Ia. Dauben's¹⁸ adaptation of the method of Grignard to vacuum-line technique (operation at *ca.* -20° ; well suited to employment of $C^{14}O_2$).

Method Ib. The method of Ruben *et al.*,¹⁹ in which a small volume of the gas ($C^{11}O_2$ or $C^{14}O_2$) is shaken with an excess of the Grignard reagent solution.

Method II. A modification of the method of Grignard attributed to Dr. H. T. Clarke of the Eastman Kodak Co.,²⁰ in which carbon dioxide is led over the surface of a stirred Grignard solution instead of directly into the solution. This method avoids clogging of the carbon dioxide delivery tube, and probably has the additional virtue of minimizing local superheating.

Method III. The method of Bodroux (*loc. cit.*¹⁶), in which carbon dioxide snow or Dry Ice in small pieces is gradually added to the Grignard reagent solution.

Method IV. The method of Fieser,²¹ in which the Grignard reagent solution is poured or dropped onto solid carbon dioxide (usually crushed).

Method IVa. The method of Fries,²² in which the Grignard solution is added to an ethereal suspension of solid carbon dioxide.

¹⁷ Kinney and Mayhue, *J. Am. Chem. Soc.*, 53, 190-9 (1931).

¹⁸ Dauben, Reid, and Yankwich, *Anal. Chem.*, 19, 828-32 (1947); Heidelberger, Brewer, and Dauben, *J. Am. Chem. Soc.*, 69, 1389-91 (1947); Dauben, *J. Org. Chem.*, 13, 313-6 (1948).

¹⁹ Ruben, Allen, and Nahinskey, *J. Am. Chem. Soc.*, 64, 3050 (1942).

²⁰ Gilman and Parker, *J. Am. Chem. Soc.*, 46, 2816-22 (1924).

²¹ Fieser, Holmes, and Newman, *J. Am. Chem. Soc.*, 58, 1055 (1936).

²² Fries and Schimmelschmidt, *Ber.*, 58B, 2835-45 (1925). See also: Hussey, *J. Am. Chem. Soc.*, 73, 1364-5 (1951).

TABLE XIII-I
REACTIONS OF GRIGNARD REAGENTS WITH CARBON DIOXIDE

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
CH₃			
CH ₃ MgI	I	CH ₃ CO ₂ H	71,87
CH ₃ MgI	Ib	CH ₃ C ¹¹ O ₂ H (ca. 95%, based on C ¹¹ O ₂)	150
CH ₃ MgI	?	CH ₃ C ¹³ O ₂ H or CH ₃ C ¹⁴ O ₂ H	38
CH ₃ MgI	?	CH ₃ C ¹⁴ O ₂ H (94%)	79
CH ₃ MgI	Ib	CH ₃ C ¹⁴ O ₂ H (ca., 95% based on C ¹⁴ O ₂)	150
C₂			
(≡CMgBr) ₂	I	(≡CCO ₂ H) ₂ (5%)	171,91,95
C₂H			
HC≡CMgBr	I	HC≡CCO ₂ H (62%)	77,210
C₂H₅			
C ₂ H ₅ MgBr	I	C ₂ H ₅ CO ₂ H (50%)	87,172
C ₂ H ₅ MgBr	I (-20°)	C ₂ H ₅ CO ₂ H (72%)	96
C ₂ H ₅ MgBr	? (-20°)	C ₂ H ₅ CO ₂ H (40%); (C ₂ H ₅) ₂ CO (20%)	33
C₃H₃			
HC≡CCH ₂ MgBr (36 g., 0.3 C ₃ H ₃ Br)	IV	HC≡CCH ₂ CO ₂ H + H ₂ C=C=CHCO ₂ H + CH ₃ C≡CCO ₂ H (aggregating 7 g., 28%, crude)	221,222
CH ₃ C≡CMgBr	I	CH ₃ C≡CCO ₂ H	92
C₃H₄F₃			
F ₃ CCH ₂ CH ₂ MgCl	III	F ₃ CCH ₂ CH ₂ CO ₂ H (43%, crude)	126

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₅			
H ₂ C=CHCH ₂ Br + Mg	V	H ₂ C=CHCH ₂ CO ₂ H (11%)	85
H ₂ C=CHCH ₂ MgBr	VIa	H ₂ C=CHCH ₂ CO ₂ H (21.7%)	59
C₃H₇			
<i>n</i> -C ₃ H ₇ MgBr	I (-20°, rapid)	<i>n</i> -C ₃ H ₇ CO ₂ H (77%)	96
RMgBr †	I (-15 to -20°)	RCO ₂ H ("high yields")	178
C₄H₃			
H ₂ C=CHC≡CMgBr	I (0°)	H ₂ C=CHC≡CCO ₂ H	25
C₄H₃O			
2-Furyl-MgBr	?	2-Furancarboxylic acid ‡	163
C₄H₃S			
2-Thienyl-MgI	I	2-Thiophenecarboxylic acid (82-100%)	157
3-Thienyl-MgBr (20 g. C ₄ H ₃ IS)	I	3-Thiophenecarboxylic acid (5 g., 42%)	223
C₄H₄N			
Pyrryl-MgBr	VIa	α-Pyrrolecarboxylic acid (32.5-42.5%)	60
Pyrryl-MgBr	VIII (250-270°)	β-Pyrrolecarboxylic acid (12%)	141
Pyrryl-MgI	I	α-Pyrrolecarboxylic acid (25-30%)	139
C₄H₅			
C ₂ H ₅ C≡CMgBr	?	C ₂ H ₅ C≡CCO ₂ H	36

* See pp. 914, 947.

† R = *n*-C₃H₇, *i*-C₃H₇, *n*-C₄H₉, *i*-C₄H₉.

‡ Furoic acid, pyromucic acid.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₇			
H ₂ C=CHCH ₂ CH ₂ MgBr	I	H ₂ C=CHCH ₂ CH ₂ CO ₂ H	188
Butenyl-MgBr	IV	CH ₃ (H ₂ C=CH)CHCO ₂ H (70%)	149
Butenyl-MgBr †	IV	CH ₃ (CH ₂ =CH)CHCO ₂ H (75%)	113
Butenyl-MgBr †	VI	H ₂ C=CHCH(CH ₃)CO ₂ H (63%); (C ₄ H ₇) ₂ CO; octadienes; high-boiling residue	113
Dibutenyl-Mg	IV	CH ₃ (H ₂ C=CH)CHCO ₂ H (37%)	149
C₄H₈			
(—CH ₂ CH ₂ MgBr) ₂	?	(CH ₂) ₄ CO	187
C₄H₉			
<i>n</i> -C ₄ H ₉ MgCl	I (−2°, rapid)	<i>n</i> -C ₄ H ₉ CO ₂ H (80%)	96
<i>n</i> -C ₄ H ₉ MgBr	I (−2°, rapid)	<i>n</i> -C ₄ H ₉ CO ₂ H (86%)	96
<i>n</i> -C ₄ H ₉ MgBr	II (0°)	<i>n</i> -C ₄ H ₉ CO ₂ H (78.9%)	60
<i>i</i> -C ₄ H ₉ MgBr	I	<i>i</i> -C ₄ H ₉ CO ₂ H (55%)	72,71
<i>s</i> -C ₄ H ₉ MgCl	II (−12 to −5°)	DL-CH ₃ (C ₂ H ₅)CHCO ₂ H (76–86%)	58
<i>s</i> -C ₄ H ₉ MgBr	II (<2°)	DL-CH ₃ (C ₂ H ₅)CHCO ₂ H (66–67%)	55,124
<i>t</i> -C ₄ H ₉ MgCl	II (0°)	<i>t</i> -C ₄ H ₉ CO ₂ H (69–70%)	145,24,65,66, 70,188
C₄H₁₁Si			
(CH ₃) ₃ SiCH ₂ MgCl	IV	(CH ₃) ₃ SiCH ₂ CO ₂ H (88%)	167
C₅H₄BrMgO			
BrMgOCH ₂ CH=CHC≡CMgBr	IX	HOCH ₂ CH=CHC≡CCO ₂ H	84

* See pp. 914, 947.

† From 80% crotyl, 20% α-methallyl bromides.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₅O			
3-Furfuryl-MgCl (13.5 g., 0.116 mole C ₅ H ₅ ClO)	IV	3-Methyl-2-furoic acid (3.9 g., 26.8%); 3-furanacetic acid (0.25 g., 1.7%, crude)	224
C₅H₅S			
2-Thenyl-MgCl (0.141 mole)	IVa	2-Thienylacetic acid (5.82 g., 29.1%); 2-methyl-3-thiophenecarboxylic acid (3.13 g., 15.6%)	226, 225
3-Thenyl-MgBr	IV	3-Methyl-2-thiophenecarboxylic acid (12.5%) [†]	227
C₅H₆BrMgO			
CH ₃ CH(OMgBr)CH ₂ C≡CMgBr	VII	CH ₃ CH(OH)CH ₂ C≡CCO ₂ H (75%)	82
C₅H₉			
CH ₃ CH=CHCH ₂ CH ₂ MgBr	I	CH ₃ CH=CHCH ₂ CH ₂ CO ₂ H	184
(CH ₂) ₄ CHMgCl	I	(CH ₂) ₄ CHCO ₂ H (55%)	203
(CH ₂) ₄ CHMgCl	VII	(CH ₂) ₄ CHCO ₂ H (51%)	138
(CH ₂) ₄ CHMgBr	III	(CH ₂) ₄ CHCO ₂ H (83%)	133
(CH ₂) ₄ CHMgBr	IVa	(CH ₂) ₄ CHCO ₂ H (86%)	90
C₅H₁₀			
H ₂ C(CH ₂ CH ₂ MgBr) ₂	I (?)	(CH ₂) ₅ CO (chief product); H ₂ C(CH ₂ CH ₂ CO ₂ H) ₂	78, 187
C₅H₁₁			
<i>i</i> -C ₅ H ₁₁ MgX	I	<i>i</i> -C ₅ H ₁₁ CO ₂ H (55%)	71
<i>t</i> -C ₅ H ₁₁ MgCl	?	<i>t</i> -C ₅ H ₁₁ CO ₂ H (60%)	24, 190

* See pp. 914, 947.

[†] Yield based on C₅H₅BrS; Grignard reagent preparation in the conventional manner (much Wurtz product).

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₃S₂			
Thiophthenyl-MgBr	?	Thiophthenecarboxylic acid	26
C₆H₄			
C ₆ H ₄ -1,4-(MgBr) ₂	I	C ₆ H ₄ -1,4-(CO ₂ H) ₂	86
C₆H₄Br			
3-BrC ₆ H ₄ MgBr	I	3-BrC ₆ H ₄ CO ₂ H (70%)	94
4-BrC ₆ H ₄ MgBr	I (36°)	4-BrC ₆ H ₄ CO ₂ H (10%); (4-BrC ₆ H ₄) ₂ CO (55%)	18
4-BrC ₆ H ₄ MgBr	I (0°)	4-BrC ₆ H ₄ CO ₂ H (61%); (4-BrC ₆ H ₄) ₂ CO (26%)	18
4-BrC ₆ H ₄ MgBr	III	4-BrC ₆ H ₄ CO ₂ H (76%); (4-BrC ₆ H ₄) ₂ CO (6%)	18
4-BrC ₆ H ₄ MgBr	I	4-BrC ₆ H ₄ CO ₂ H (70%)	94
C₆H₄BrMgO			
2-BrMgOC ₆ H ₄ MgBr	I	2-HOC ₆ H ₄ CO ₂ H (20%)	135
C₆H₄Cl			
4-ClC ₆ H ₄ MgBr	I (36°)	4-ClC ₆ H ₄ CO ₂ H (24%); (4-ClC ₆ H ₄) ₂ CO (50%)	18
4-ClC ₆ H ₄ MgBr	I (0°)	4-ClC ₆ H ₄ CO ₂ H (64%); (4-ClC ₆ H ₄) ₂ CO (18%)	18
4-ClC ₆ H ₄ MgBr	III	4-ClC ₆ H ₄ CO ₂ H (80%); (4-ClC ₆ H ₄) ₂ CO (4%)	18
4-XC ₆ H ₄ MgBr [†]	I (cold)	4-XC ₆ H ₄ CO ₂ H (predominating); (4-XC ₆ H ₄) ₂ CO	16
4-XC ₆ H ₄ MgBr [†]	I (36°)	(4-XC ₆ H ₄) ₂ CO (predominating); 4-XC ₆ H ₄ CO ₂ H	16
C₆H₅			
C ₆ H ₅ MgCl	I	C ₆ H ₅ CO ₂ H (39%)	104

* See pp. 914, 947.

[†] X = Cl, Br.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₅ (cont.)			
C ₆ H ₅ MgCl	I (?)	C ₆ H ₅ CO ₂ H; 4-C ₆ H ₅ C ₆ H ₄ CO ₂ H; 4-(<i>p</i> -C ₆ H ₅ C ₆ H ₄)C ₆ H ₄ -1-CO ₂ H	122
C ₆ H ₅ MgBr	I	C ₆ H ₅ CO ₂ H (50%)	172,87
C ₆ H ₅ MgBr	I (cold)	C ₆ H ₅ CO ₂ H (88.5-91.0%)	128
C ₆ H ₅ MgBr	I (-20°, rapid)	C ₆ H ₅ CO ₂ H (80%)	96
C ₆ H ₅ MgBr	I (ice-cooled)	C ₆ H ₅ CO ₂ H; (C ₆ H ₅) ₃ COH	15
C ₆ H ₅ MgBr	I (hot)	[(C ₆ H ₅) ₃ CO—] ₂	15
C ₆ H ₅ MgBr	I (36°)	C ₆ H ₅ CO ₂ H (16%); (C ₆ H ₅) ₂ CO (13%); (C ₆ H ₅) ₃ COH (32%)	162
C ₆ H ₅ MgBr	I (hot Et ₂ O, rapid)	C ₆ H ₅ CO ₂ H (17.4%); (C ₆ H ₅) ₂ CO (20.2%); (C ₆ H ₅) ₃ COH (25.7%); [(C ₆ H ₅) ₃ CO—] ₂	62
C ₆ H ₅ MgBr	I (hot Et ₂ O, 6 hrs.)	C ₆ H ₅ CO ₂ H (16.3%); (C ₆ H ₅) ₃ COH (36.9%); (C ₆ H ₅) ₃ CH (3.08%)	62
C ₆ H ₅ MgBr	I (hot C ₆ H ₆ , 10 hrs.)	(C ₆ H ₅) ₃ COH (46.2%); (C ₆ H ₅) ₃ CH (2.4%)	62
C ₆ H ₅ MgBr	I (hot C ₆ H ₆ , 16 hrs.)	(C ₆ H ₅) ₃ COH (44.5%); (C ₆ H ₅) ₃ CH (1.2%)	62
C ₆ H ₅ MgBr	I (hot C ₇ H ₈ , 4 hrs.)	(C ₆ H ₅) ₃ COH (41.6%); (C ₆ H ₅) ₃ CH (3.08%)	62
C ₆ H ₅ MgBr	I (hot cymene, 9 hrs.)	(C ₆ H ₅) ₃ COH (46.8%)	62
C ₆ H ₅ MgBr	Ia (-20°)	C ₆ H ₄ C ¹⁴ O ₂ H (85.4%)	32
C ₆ H ₅ MgBr	II (0°)	C ₆ H ₅ CO ₂ H (71.5-72.5%)	62
C ₆ H ₅ MgBr	IVa	C ₆ H ₅ CO ₂ H (91%)	90
C ₆ H ₅ MgBr	IX†	C ₆ H ₅ CH ₂ OH; (C ₆ H ₅) ₃ COH; (C ₆ H ₅) ₂ CO; C ₆ H ₅ CO ₂ H; C ₆ H ₅ OH	130
C ₆ H ₅ MgI	I	C ₆ H ₅ CO ₂ H (60%)	200
C₆H₆Br			
H ₂ C=CBr(CH ₂) ₂ C≡CMgBr	I	H ₂ C=CBr(CH ₂) ₂ C≡CCO ₂ H (40%)	93

* See pp. 914, 947.

† Equivalent of C₆H₅MgBr saturated with CO₂; then treated with two equivalents of C₆H₅MgBr (?) or RMgX (?).

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₆IO			
2,5-Dimethyl-4-iodo-3-furyl-MgI	IV	2,5-Dimethyl-4-iodo-3-furoic acid	89
C₆H₇S			
5-Methyl-3-thienyl-MgBr	?	2,5-Dimethyl-3-thiophenecarboxylic acid	228
2,5-Dimethyl-3-thienyl-MgI	I (0°)	2,5-Dimethyl-3-thiophenecarboxylic acid (40%)	170,218
C₆H₈ClMgO₂			
[C ₂ H ₅ CH=CHCH(CO ₂ MgCl)] ⁻ MgCl ⁺	I (cold)	C ₂ H ₅ CH=CHCH(CO ₂ H) ₂	98
C₆H₉			
<i>n</i> -C ₃ H ₇ C≡CCH ₂ MgBr (32 g., 0.2 mole C ₆ H ₉ Br)	IV	<i>n</i> -C ₃ H ₇ C≡CCH ₂ CO ₂ H (16%); <i>n</i> -C ₃ H ₇ C(CO ₂ H)=C=CH ₂ (38%); dimeric acid (12%); acidic residue (6%)	229
C₆H₉O			
CH ₃ (C ₂ H ₅ O)CHC≡CMgBr	?	CH ₃ (C ₂ H ₅ O)CHC≡CCO ₂ H	69,211
CH ₃ (C ₂ H ₅)C(OH)C≡CMgBr	I (0°)	CH ₃ (C ₂ H ₅)C(OH)C≡CCO ₂ H (20%)	129
C₆H₁₁			
CH ₃ CH=CH(CH ₂) ₃ MgBr	I	CH ₃ CH=CH(CH ₂) ₃ CO ₂ H	183
(CH ₂) ₅ CHMgCl	I	(CH ₂) ₅ CHCO ₂ H (55%)	136,23,154
(CH ₂) ₅ CHMgCl	II (0°)	(CH ₂) ₅ CHCO ₂ H (68%)	60,219
(CH ₂) ₅ CHMgCl	III	(CH ₂) ₅ CHCO ₂ H (81%)	134
(CH ₂) ₅ CHMgBr	?	Cyclohexene; (CH ₂) ₅ CHOH; (CH ₂) ₅ CHCH ₂ OH; [(CH ₂) ₅ CH] ₂ CH ₂ ; [(CH ₂) ₅ CH] ₂ CHOH	130

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₁ (cont.)			
(CH ₂) ₅ CHMgBr † (+ <i>n</i> -C ₃ H ₇ MgBr)	?	(CH ₂) ₅ CHCO ₂ H (80%); (CH ₂) ₅ CHCH ₂ OH (20%); <i>n</i> -C ₃ H ₇ OH	130
(CH ₂) ₅ CHMgI	I	(CH ₂) ₅ CHCO ₂ H (35%)	199
(CH ₂) ₄ C(CH ₃)MgCl (53 g. C ₆ H ₁₁ Cl)	I	(CH ₂) ₄ C(CH ₃)CO ₂ H (12 g.)	212, 176
3-Methylcyclopentyl-MgI	I	3-Methylcyclopentanecarboxylic acid	199
C₆H₁₂			
[—(CH ₂) ₃ MgBr] ₂	I	[—(CH ₂) ₃ CO ₂ H] ₂ (poor yield)	204
C₆H₁₃			
<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ MgBr	III	<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ CO ₂ H (78%)	197
CH ₃ (C ₂ H ₅) ₂ CMgCl	II, ?	CH ₃ (C ₂ H ₅) ₂ CCO ₂ H (27%, 42%)	230, 189
C₆H₁₇OSi₂			
(CH ₃) ₃ SiOSi(CH ₃) ₂ CH ₂ MgCl	IV	(CH ₃) ₃ SiOSi(CH ₃) ₂ CH ₂ CO ₂ H (85%)	167
C₇H₄F₃			
2-F ₃ CC ₆ H ₄ MgBr	IV	2-F ₃ CC ₆ H ₄ CO ₂ H (85.7%)	105
2-F ₃ CC ₆ H ₄ MgI	IV	2-F ₃ CC ₆ H ₄ CO ₂ H (73.4%)	105
4-F ₃ CC ₆ H ₄ MgBr	IV	4-F ₃ CC ₆ H ₄ CO ₂ H (90.0%)	105
C₇H₅Cl₂			
2,6-Cl ₂ C ₆ H ₃ CH ₂ MgCl	I	2,6-Cl ₂ C ₆ H ₃ CH ₂ CO ₂ H	7
C₇H₆Cl			
2-ClC ₆ H ₄ CH ₂ MgCl	I	2-ClC ₆ H ₄ CH ₂ CO ₂ H	7

* See pp. 914, 947.

† One equivalent of (CH₂)₅CHMgBr saturated with CO₂; then treated with two equivalents of *n*-C₃H₇MgBr.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₇			
C ₆ H ₅ CH ₂ MgCl	I	C ₆ H ₅ CH ₂ CO ₂ H (60%)	87,196,200
C ₆ H ₅ CH ₂ MgCl	I (-20°, rapid)	C ₆ H ₅ CH ₂ CO ₂ H (79%)	96
C ₆ H ₅ CH ₂ MgCl	IVa	C ₆ H ₅ CH ₂ CO ₂ H (40%, crude)	7
C ₆ H ₅ CH ₂ MgBr	I	C ₆ H ₅ CH ₂ CO ₂ H (10%)	87
2-CH ₃ C ₆ H ₄ MgBr	IVa	2-CH ₃ C ₆ H ₄ CO ₂ H (62%)	7
C₇H₇O			
4-CH ₃ OC ₆ H ₄ MgBr	I	4-CH ₃ OC ₆ H ₄ CO ₂ H	19
4-CH ₃ OC ₆ H ₄ MgBr	IVa	4-CH ₃ OC ₆ H ₄ CO ₂ H (92%)	90
C₇H₁₁			
<i>n</i> -C ₄ H ₉ C≡CCH ₂ MgBr	IV	<i>n</i> -C ₄ H ₉ C≡CCH ₂ CO ₂ H (9%); <i>n</i> -C ₄ H ₉ C(CO ₂ H)=C=CH ₂ (41%); dimeric acid and acidic residue (7%)	229
C₇H₁₃			
(CH ₂) ₆ CHMgBr	I	(CH ₂) ₆ CHCO ₂ H (40%)	199
(CH ₂) ₅ C(CH ₃)MgCl	I	1-Methylcyclohexanecarboxylic acid (25%)	80,127
2-Methylcyclohexyl-MgCl	I	2-Methylcyclohexanecarboxylic acid (62%)	80,132
3-Methylcyclohexyl-MgCl	I	3-Methylcyclohexanecarboxylic acid (63%)	80
3-Methylcyclohexyl-MgCl	?	3-Methylcyclohexanecarboxylic acid (2 isomers in ratio of 60A:40B)	131
3-Methylcyclohexyl-MgI	I	3-Methylcyclohexanecarboxylic acid (35%)	199
3-Methylcyclohexyl-MgI (from "active" iodide)	?	3-Methylcyclohexanecarboxylic acid (A isomer)	131
4-Methylcyclohexyl-MgCl	I	4-Methylcyclohexanecarboxylic acid (52.5%)	80

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₃O			
H ₂ C=CH[CH ₃ O(CH ₂) ₃]CHMgCl	IVA	H ₂ C=CH[CH ₃ O(CH ₂) ₃]CHCO ₂ H (38%)	205
C₇H₁₄			
H ₂ C[(CH ₂) ₃ MgBr] ₂	?	H ₂ C[(CH ₂) ₃ CO ₂ H] ₂	187
C₇H₁₄O			
H ₂ C=CH[CH ₃ O(CH ₂) ₃]CHMgCl (22.3 g., 0.15 mole C ₇ H ₁₄ ClO)	IVA	H ₂ C=CH[CH ₃ O(CH ₂) ₃]CHCO ₂ H (8.92 g., 38%)	213
C₇H₁₅			
(C ₂ H ₅) ₃ CMgCl	?	(C ₂ H ₅) ₃ CCO ₂ H	193
<i>n</i> -C ₄ H ₉ (CH ₃) ₂ CMgCl	VII (60 mm., 0°)	<i>n</i> -C ₄ H ₉ (CH ₃) ₂ CCO ₂ H	189
C₇H₁₅O			
C ₂ H ₅ [CH ₃ O(CH ₂) ₃]CHMgCl	IV	C ₂ H ₅ [CH ₃ O(CH ₂) ₃]CHCO ₂ H (64%)	205
C₈H₅			
C ₆ H ₅ C≡CMgBr	I	C ₆ H ₅ C≡CCO ₂ H (55%); C ₆ H ₅ C≡CH (21%)	107, 173
C ₆ H ₅ C≡CMgBr	I (-10 to 0°, or -40 to -30°)	Unstable, unidentified oil	101
C₈H₅BrClMgO₂			
[2-BrC ₆ H ₄ CH(CO ₂ MgCl)] ⁻ MgX ⁺	I (cold)	2-BrC ₆ H ₄ CH(CO ₂ H) ₂	97
[3-BrC ₆ H ₄ CH(CO ₂ MgCl)] ⁻ MgX ⁺	I (cold)	3-BrC ₆ H ₄ CH(CO ₂ H) ₂	97
C₈H₅Cl₂MgO₂			
[2-ClC ₆ H ₄ CH(CO ₂ MgCl)] ⁻ MgX ⁺	1 (0°)	2-ClC ₆ H ₄ CH(CO ₂ H) ₂ (46.2-52.8%)	99

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₅Cl₂MgO₂ (cont.)			
[3-ClC ₆ H ₄ CH(CO ₂ MgCl)]-MgX ⁺	I (cold)	3-ClC ₆ H ₄ CH(CO ₂ H) ₂	97
[4-ClC ₆ H ₄ CH(CO ₂ MgCl)]-MgX ⁺	I (0°)	4-ClC ₆ H ₄ CH(CO ₂ H) ₂ (48.3-56.4%)	99
C₆H₅ClMgO₂			
[C ₆ H ₅ CH(CO ₂ MgCl)]-MgX ⁺	I (0°)	C ₆ H ₅ CH(CO ₂ H) ₂ (40-66%) [†]	99
C₈H₆N			
Indolyl-Mgl	?	N-Indolecarboxylic acid	142
Indolyl-Mgl	I (<0°)	β-Indolecarboxylic acid (8.6% in Et ₂ O; 25% in MeOPh)	120
C₈H₆NS			
2-Benzothiazolylmethyl-MgBr	?	2-Benzothiazoleacetic acid	29
C₈H₇			
C ₆ H ₅ CH=CHMgBr	?	C ₆ H ₅ CH=CHCO ₂ H	173
C₈H₉			
C ₆ H ₅ (CH ₂) ₂ MgBr	I	C ₆ H ₅ CH ₂ CH ₂ CO ₂ H (50%)	73
2-CH ₃ C ₆ H ₄ CH ₂ MgBr	II	2-CH ₃ C ₆ H ₄ CH ₂ CO ₂ H	231
3-CH ₃ C ₆ H ₄ CH ₂ MgBr	II	2,6-(CH ₃) ₂ C ₆ H ₃ CO ₂ H (?)	231; cf. 206

* See pp. 914, 947.

[†] The Grignard reagent, or, as has been suggested by Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), the enolate, is prepared by the action of an organomagnesium halide on C₆H₅CH₂CO₂MgCl. The overall yield of phenylmalonic acid depends upon the organomagnesium halide used. C₂H₅MgBr, 62.5%; *i*-C₃H₇MgCl, 65.6%; *i*-C₃H₇MgBr, 48.9%; *n*-C₃H₇MgCl, 45.0%; *n*-C₄H₉MgBr, 42.2%; (CH₂)₅CHMgBr, 40.0%; 2-CH₃C₆H₄MgBr, 50.6%; 1-C₁₀H₇MgBr, 53.3%; C₆H₅CH₂MgCl, 3.1%; CH₃MgI, negligible.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₉ (<i>cont.</i>)			
4-CH ₃ C ₆ H ₄ CH ₂ MgBr	II	4-CH ₃ C ₆ H ₄ CH ₂ CO ₂ H (90x%); 2,5-(CH ₃) ₂ C ₆ H ₃ CO ₂ H (10x%)	231
C₈H₉O			
CH ₃ OCH ₂ C≡CCH ₂ CH ₂ C≡CMgI	?	CH ₃ OCH ₂ C≡CCH ₂ CH ₂ C≡CCO ₂ H	114
4-CH ₃ OC ₆ H ₄ CH ₂ MgBr	II	4-CH ₃ OC ₆ H ₄ CH ₂ CO ₂ H	67
4-C ₂ H ₅ OC ₆ H ₄ MgBr	I	4-C ₂ H ₅ OC ₆ H ₄ CO ₂ H ("good yield")	19
C₈H₉O₂			
3,4-(CH ₃ O) ₂ C ₆ H ₃ MgI	I	3,4-(CH ₃ O) ₂ C ₆ H ₃ CO ₂ H	106
C₈H₉O₂S			
CH ₃ (C ₆ H ₅ SO ₂)CHMgBr	?	Acidic gum	232
C₈H₁₀N			
2-(CH ₃) ₂ NC ₆ H ₄ MgBr	?	2-(CH ₃) ₂ NC ₆ H ₄ CO ₂ H	233
C₈H₁₃			
<i>n</i> -C ₅ H ₁₁ C≡CCH ₂ MgBr	IV	<i>n</i> -C ₅ H ₁₁ C≡CCH ₂ CO ₂ H (13%); <i>n</i> -C ₅ H ₁₁ C(CO ₂ H)=C=CH ₂ (23%); dimeric acid (3%); acidic residue (13%)	229
CH ₃ (<i>n</i> -C ₄ H ₉ C≡C)CHMgBr	IV	Acidic material (7.0 g., 41.6%), including <i>n</i> -C ₄ H ₉ C(CO ₂ H)=C=CHCH ₃ (3.4 g., 20.0%)	234
C₈H₁₅			
Octenyl-MgBr †	?	H ₂ C=CH[CH ₃ (CH ₂) ₄]CHCO ₂ H	235

* See pp. 914, 947.

† From mixture of CH₃(CH₂)₄CH=CHCH₂Br and H₂C=CH[CH₃(CH₂)₄]CHBr.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₅ (<i>cont.</i>)			
3,5-Dimethylcyclohexyl-MgI	I	3,5-Dimethylcyclohexanecarboxylic acid ($<35\%$)	199
C₈H₁₅O			
[<i>t</i> -C ₄ H ₉ COC(CH ₃) ₂]-MgBr [†]	I	<i>t</i> -C ₄ H ₉ COC(CH ₃) ₂ CO ₂ H	179
4-(Tetrahydro-2-furyl)-2-butyl-MgBr	II	α -Methyl- γ -tetrahydro-2-furylbutyric acid (59%)	50
C₈H₁₇			
<i>t</i> -C ₄ H ₉ (CH ₃) ₂ CCH ₂ MgCl	I (-5°)	<i>t</i> -C ₄ H ₉ (CH ₃) ₂ CCH ₂ CO ₂ H (59%)	194
<i>t</i> -C ₄ H ₉ CH ₂ C(CH ₃) ₂ MgCl	?	<i>t</i> -C ₄ H ₉ CH ₂ C(CH ₃) ₂ CO ₂ H (34%)	207
<i>n</i> -C ₅ H ₁₁ (CH ₃) ₂ CMgCl	VII (80 mm., 0°)	<i>n</i> -C ₅ H ₁₁ (CH ₃) ₂ CCO ₂ H (22%)	189
C₉H₇			
C ₆ H ₅ C \equiv CCH ₂ MgBr	I	C ₆ H ₅ C \equiv CCH ₂ CO ₂ H; C ₆ H ₅ C(CO ₂ H)=C=CH ₂ [†]	236 236
1-Indenyl-MgBr	I	1-Indenecarboxylic acid	100,75
2-Indenyl-MgBr	?	2-Indenecarboxylic acid (15%)	144
3-Indenyl-MgBr	I	3-Indenecarboxylic acid	100
C₉H₇S			
2-Thianaphthenylmethyl-MgCl	IVa	2-Methyl-3-thianaphthenecarboxylic acid (<i>ca.</i> 45%)	237
3-Thianaphthenylmethyl-MgCl (0.3 mole)	IVa	3-Methyl-2-thianaphthenecarboxylic acid (32.2 g., 56%); 3-thianaphtheneacetic acid (9.4 g., 16%)	238

* See pp. 914, 947.

[†] Carbonation must be carried out in absence of oxygen and peroxides; otherwise polymeric material only is obtained.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₈ClMgO₂			
[2-CH ₃ C ₆ H ₄ CH(CO ₂ MgCl)] ⁻ MgX ⁺	I (cold)	2-CH ₃ C ₆ H ₄ CH(CO ₂ H) ₂	97
[3-CH ₃ C ₆ H ₄ CH(CO ₂ MgCl)] ⁻ MgX ⁺	I (cold)	3-CH ₃ C ₆ H ₄ CH(CO ₂ H) ₂	97
[4-CH ₃ C ₆ H ₄ CH(CO ₂ MgCl)] ⁻ MgX ⁺	I (cold)	4-CH ₃ C ₆ H ₄ CH(CO ₂ H) ₂	97
C₉H₈N			
2-Methylindolyl-MgBr	I (36°)	α-Methylindole-N-carboxylic acid; α-methylindole-β-carboxylic acid (14%)	140
2-Methylindolyl-MgBr	I (b.p. C ₇ H ₈)	α-Methylindole-β-carboxylic acid (63%)	140
3-Methylindolyl-MgBr	I (36°)	β-Methylindole-N-carboxylic acid	140
3-Methylindolyl-MgBr	VIII (315-320°)	β-Methylindole-α-carboxylic acid (50%)	140
C₉H₉			
C ₉ H ₉ MgCl (from cinnamyl chloride)	?	H ₂ C=CH(C ₆ H ₅)CHCO ₂ H	52,51,53
C ₆ H ₅ CH ₂ CH=CHMgBr	I	C ₆ H ₅ CH ₂ CH=CHCO ₂ H	185
CH ₃ (C ₆ H ₅)C=CHMgBr	?	CH ₃ (C ₆ H ₅)C=CHCO ₂ H (2 isomers)	173
C ₆ H ₅ CH ₂ C(=CH ₂)MgBr	I	C ₆ H ₅ CH ₂ C(=CH ₂)CO ₂ H	185
4-H ₂ C=CHCH ₂ C ₆ H ₄ MgBr	I	4-H ₂ C=CHCH ₂ C ₆ H ₄ CO ₂ H	146
4-CH ₃ CH=CHC ₆ H ₄ MgBr	I (0°)	4-CH ₃ CH=CHC ₆ H ₄ CO ₂ H (30%)	146
C₉H₁₁			
C ₆ H ₅ (CH ₂) ₃ MgBr	I	C ₆ H ₅ (CH ₂) ₃ CO ₂ H	152,218
CH ₃ (C ₆ H ₅)CHCH ₂ MgCl	?	CH ₃ (C ₆ H ₅)CHCH ₂ CO ₂ H	117
CH ₃ (C ₆ H ₅)CHCH ₂ MgBr	?	CH ₃ (C ₆ H ₅)CHCH ₂ CO ₂ H	119

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₁ (cont.)			
CH ₃ (C ₆ H ₅ CH ₂)CHMgBr (22.0 g. C ₉ H ₁₁ Br)	IV	CH ₃ (C ₆ H ₅ CH ₂)CHCO ₂ H (7.6 g., 42%)	214
2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	I	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ H (<i>ca.</i> quant.)	111
2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	I	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ H (53.7%)	165
2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	II	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ H (50%)	54
2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	IV	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ H (60%)	5
2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	VI	2,4,6-(CH ₃) ₃ C ₆ H ₂ CO ₂ H (84%)	5
C₉H₁₁O			
2,6-(CH ₃) ₂ -4-CH ₃ OC ₆ H ₂ MgBr	IV	2,6-(CH ₃) ₂ -4-CH ₃ OC ₆ H ₂ CO ₂ H (69%)	44
C₉H₁₃Si			
C ₆ H ₅ (CH ₃) ₂ SiCH ₂ MgCl	IV	C ₆ H ₅ (CH ₃) ₂ SiCH ₂ CO ₂ H (69%)	167
C₉H₁₅			
<i>n</i> -C ₄ H ₉ C≡C(CH ₃) ₂ CMgBr	IV	<i>n</i> -C ₄ H ₉ C(CO ₂ H)=C=C(CH ₃) ₂ (4.4 g., 9.5%)	234
C₉H₁₅IMgO			
<i>t</i> -C ₄ H ₉ C(CH ₃)(OMgI)C(CH ₃) ₂ MgBr	I	<i>t</i> -C ₄ H ₉ C(OH)(CH ₃)C(CH ₃) ₂ CO ₂ H	179
C₁₀H₆			
C ₁₀ H ₆ -1,2-(MgBr) ₂	I	C ₁₀ H ₆ -1,2-(CO ₂ H) ₂ (very little)	155
C ₁₀ H ₆ -1,4-(MgBr) ₂	I (-20°)	C ₁₀ H ₆ -1,4-(CO ₂ H) ₂ (51%)	155
C ₁₀ H ₆ -1,5-(MgBr) ₂	I (-18°)	C ₁₀ H ₆ -1,5-(CO ₂ H) ₂ (<i>ca.</i> quant.)	155
C₁₀H₆Br			
4-BrC ₁₀ H ₆ -1-MgBr	I	4-BrC ₁₀ H ₆ -1-CO ₂ H (20%)	86

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₆Br (<i>cont.</i>)			
4-BrC ₁₀ H ₆ -1-MgBr	I (-20°)	4-BrC ₁₀ H ₆ -1-CO ₂ H (77%)	155
5-BrC ₁₀ H ₆ -2-MgBr	I	5-BrC ₁₀ H ₆ -2-CO ₂ H	40
C₁₀H₆Cl			
4-ClC ₁₀ H ₆ -1-MgI	?	4-ClC ₁₀ H ₆ -1-CO ₂ H	168
C₁₀H₇			
1-C ₁₀ H ₇ MgCl	I	1-C ₁₀ H ₇ CO ₂ H (16%)	104
1-C ₁₀ H ₇ MgBr	I	1-C ₁₀ H ₇ CO ₂ H (65-70%)	15, 1, 86, 191
1-C ₁₀ H ₇ MgBr	Ia (0°)	1-C ₁₀ H ₇ C ¹⁴ O ₂ H (82.4%)	30
1-C ₁₀ H ₇ MgBr	II	1-C ₁₀ H ₇ CO ₂ H (68-70%)	63
1-C ₁₀ H ₇ MgBr	III	1-C ₁₀ H ₇ CO ₂ H (80-90%)	32
1-C ₁₀ H ₇ MgBr	IV	1-C ₁₀ H ₇ CO ₂ H (85%)	39
1-C ₁₀ H ₇ MgBr	IVa	1-C ₁₀ H ₇ CO ₂ H (89%)	90
2-C ₁₀ H ₇ MgBr	I	2-C ₁₀ H ₇ CO ₂ H (65%)	155
2-C ₁₀ H ₇ MgBr	Ia (-20°)	2-C ₁₀ H ₇ C ¹⁴ O ₂ H (73%)	83
2-C ₁₀ H ₇ MgBr	II	2-C ₁₀ H ₇ CO ₂ H (62.7%, crude)	61
C₁₀H₈MgO₂X			
[C ₆ H ₅ CH=CHCH(CO ₂ MgX)]-MgX +	I (cold)	C ₆ H ₅ CH=CHCH(CO ₂ H) ₂	98
C₁₀H₉S			
3-Methyl-2-thianaphthenyl-MgBr (22.7 g. C ₁₀ H ₉ BrS)	IVa	3-Methyl-2-thianaphthenecarboxylic acid (7.9 g., 41%)	238
C₁₀H₁₁			
7-Methyl-4-indanyl-MgBr	Ia (0°)	7-Methylindan-4-carboxylic acid (64%)	30

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₃			
C ₂ H ₅ (C ₆ H ₅)CHCH ₂ MgBr	?	C ₂ H ₅ (C ₆ H ₅)CHCH ₂ CO ₂ H	119
(+)-C ₂ H ₅ (C ₆ H ₅)CHCH ₂ MgCl	?	(+)-C ₂ H ₅ (C ₆ H ₅)CHCH ₂ CO ₂ H	117
(-)-C ₆ H ₅ CH ₂ CH(CH ₃)CH ₂ MgBr	?	(+)-C ₆ H ₅ CH ₂ CH(CH ₃)CH ₂ CO ₂ H	118
4- <i>s</i> -C ₄ H ₉ C ₆ H ₄ MgBr	IVa (?)	4- <i>s</i> -C ₄ H ₉ C ₆ H ₄ CO ₂ H (50%)	49
4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ MgBr	IVa	4- <i>t</i> -C ₄ H ₉ C ₆ H ₄ CO ₂ H (55%)	49
2,3,5,6-(CH ₃) ₄ C ₆ H ₂ MgBr	IV	2,3,5,6-(CH ₃) ₄ C ₆ H ₂ CO ₂ H (55%)	47
2-CH ₃ -5- <i>i</i> -C ₃ H ₇ C ₆ H ₃ MgBr	VII (<0°)	2-CH ₃ -5- <i>i</i> -C ₃ H ₇ C ₆ H ₃ CO ₂ H (35-40%)	21
3-CH ₃ -6- <i>i</i> -C ₃ H ₇ C ₆ H ₃ MgBr	VII (<-5°)	3-CH ₃ -6- <i>i</i> -C ₃ H ₇ C ₆ H ₃ CO ₂ H (<i>ca.</i> 55%, crude)	21
3-CH ₃ -6- <i>i</i> -C ₃ H ₇ C ₆ H ₃ MgBr	III	3-CH ₃ -6- <i>i</i> -C ₃ H ₇ C ₆ H ₃ CO ₂ H (56%)	116
C₁₀H₁₃O			
2,4,6-(CH ₃) ₃ -3-CH ₃ OC ₆ H ₂ MgBr	III	2,4,6-(CH ₃) ₃ -3-CH ₃ OC ₆ H ₂ CO ₂ H (43%)	44
C₁₀H₁₅O			
(C ₁₀ H ₁₅ O) ⁻ MgBr ⁺ (from α -bromo-camphor and Mg)	I (36°)	(C ₁₀ H ₁₅ O)CO ₂ H (26%)	121,202
C₁₀H₁₇			
C ₁₀ H ₁₇ MgCl [†]	I	(\pm)-Camphanecarboxylic acid	180,148,86
Bornyl-MgCl [†]	I	(+)-Camphane-2-carboxylic acid	180,148,151
"Bornyl-MgI"	I	Camphane-2-carboxylic acid	201

* See pp. 914, 947.

[†] From (+)- α -pinene hydrochloride; Rivi  re (148) concludes that this Grignard reagent is an equimolecular mixture of bornylmagnesium and isobornylmagnesium chlorides.

[†] Prepared by refluxing in xylene (three hours at 130°) the Grignard reagent from (+)- α -pinene hydrochloride; Rivi  re (148) concludes that the reagent so obtained is substantially pure bornylmagnesium chloride.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₇ (cont.)			
Isobornyl-MgCl †	I	(-)-Camphane-2-carboxylic acid	180,148
C₁₀H₁₈			
C ₁₀ H ₁₈ (MgCl) ₂ †	I	<i>p</i> -Menthane-1,8-dicarboxylic acid	12
C₁₀H₁₉			
C ₁₀ H ₁₉ MgBr (from 3-bromo- <i>p</i> -menthane)	I	<i>p</i> -Menthane-3-carboxylic acid	201
C₁₀H₂₀			
[-(CH ₂) ₅ MgI] ₂	?	[-(CH ₂) ₅ CO ₂ H] ₂	187
C₁₀H₂₁			
<i>n</i> -C ₁₀ H ₂₁ MgBr	Ia (-20°)	<i>n</i> -C ₁₀ H ₂₁ C ¹⁴ O ₂ H (yielding 79.3% methyl ester)	62
C₁₁H₉			
1-C ₁₀ H ₇ CH ₂ MgCl	II	1-C ₁₀ H ₇ CH ₂ CO ₂ H (59.4%)	57
2-C ₁₀ H ₇ CH ₂ MgBr	II	2-C ₁₀ H ₇ CH ₂ CO ₂ H	57
2-CH ₃ C ₁₀ H ₆ -1-MgBr	III	2-CH ₃ C ₁₀ H ₆ -1-CO ₂ H (72%)	46
C₁₁H₉ClO			
2,4-(CH ₃) ₂ -3-Cl-6-CH ₃ OC ₆ HC≡ CMgBr	?	2,4-(CH ₃) ₂ -3-Cl-6-CH ₃ OC ₆ HC≡CCO ₂ H (55%, crude)	4

* See pp. 914, 947.

† Prepared by partial (66%) carbonation of the Grignard reagent from (+)- α -pinene hydrochloride; Rivière (148) concludes that the residual reagent is substantially pure isobornylmagnesium chloride.

‡ From 1,8-dichloro-*p*-menthane.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₉O			
2-CH ₃ OC ₁₀ H ₆ -1-MgBr	I	2-CH ₃ OC ₁₀ H ₆ -1-CO ₂ H (<i>ca.</i> 20%)	17
4-CH ₃ OC ₁₀ H ₆ -1-MgBr		4-CH ₃ OC ₁₀ H ₆ -1-CO ₂ H (84%)	168
6-CH ₃ OC ₁₀ H ₆ -2-MgBr	IVa	6-CH ₃ OC ₁₀ H ₆ -2-CO ₂ H (50%)	41
C₁₁H₁₂ClMgO₂			
[4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH(CO ₂ MgCl)]-MgX ⁺	I (cold)	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH(CO ₂ H) ₂	97
C₁₁H₁₂ClO₂			
[2,4-(CH ₃) ₂ -3-Cl-6-CH ₃ -OC ₆ HCOCH ₂]-MgBr ⁺	VII (2-3 atm.)	2,4-(CH ₃) ₂ -3-Cl-6-CH ₃ OC ₆ HCOCH ₂ CO ₂ H (45%)	3
C₁₁H₁₃			
2-Phenylcyclopentyl-MgBr	?	2-Phenylcyclopentanecarboxylic acid (25%)	186
3-Phenylcyclopentyl-MgBr	I (cold)	3-Phenylcyclopentanecarboxylic acid (70%)	22
2-Methyl-5,6,7,8-tetrahydro-1-naphthyl-MgBr	I	2-Methyl-5,6,7,8-tetrahydro-1-naphthoic acid	125
C₁₁H₁₃O			
[2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂]-MgBr ⁺	VII	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH ₂ CO ₂ H	45, 111
C₁₁H₁₄			
H ₂ C[(CH ₂) ₃ C≡CMgBr] ₂	I (?)	H ₂ C[(CH ₂) ₃ C≡CCO ₂ H] ₂	114, 115
C₁₁H₁₅			
C ₆ H ₅ (CH ₂) ₅ MgBr	?	C ₆ H ₅ (CH ₂) ₅ CO ₂ H	218
<i>t</i> -C ₄ H ₉ (C ₆ H ₅)CHMgBr (10 g. C ₁₁ H ₁₅ Br)	?	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)CHCO ₂ H (1.1 g., 13%) [†]	239

* See pp. 914, 947.

[†] Yield based on C₁₁H₁₅Br; much Wurtz product formed in preparation of Grignard reagent.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₅ (<i>cont.</i>)			
(CH ₃) ₅ C ₆ MgBr	I (0°)	(CH ₃) ₅ C ₆ CO ₂ H (39%); (CH ₃) ₅ C ₆ C ₂ H ₅	28,27,74
(CH ₃) ₅ C ₆ MgBr [from 0.2 mole (CH ₃) ₅ C ₆ Br + 0.2 mole C ₂ H ₅ Br + Mg]	I (0°)	(CH ₃) ₅ C ₆ Br (2 g.); (CH ₃) ₅ C ₆ C ₂ H ₅ (17 g.); (CH ₃) ₅ C ₆ CO ₂ H (15 g.); (CH ₃) ₅ C ₆ H (2 g.); C ₂ H ₅ CO ₂ H	156
(CH ₃) ₅ C ₆ Br + C ₂ H ₅ Br + Mg	V (0°)	(CH ₃) ₅ C ₆ CO ₂ H (39%); (CH ₃) ₅ C ₆ C ₂ H ₅ (48.3%)	156
C₁₁H₂₃			
<i>n</i> -C ₁₁ H ₂₃ MgBr	I (with N ₂ ; -40°)	<i>n</i> -C ₁₁ H ₂₃ C ¹⁴ O ₂ H (57%)	81
C₁₂H₇O			
1-Dibenzofuryl-MgBr	III	1-Dibenzofurancarboxylic acid (90%)	64,103
4-Dibenzofuryl-MgBr (16.8 g., 0.1 mole C ₁₂ H ₈ O)	III	4-Dibenzofurancarboxylic acid (1.05 g., 5%)	240
C₁₂H₆			
(-C ₆ H ₄ -3-MgBr) ₂	IV	(-C ₆ H ₄ -3-CO ₂ H) ₂ (40%)	166
C₁₂H₆Br			
3-BrC ₆ H ₄ C ₆ H ₄ -3-MgBr	IV	3-BrC ₆ H ₄ C ₆ H ₄ -3-CO ₂ H (<i>ca.</i> 21%); (-C ₆ H ₄ -3-CO ₂ H) ₂	166
C₁₂H₈ClMgO₂			
[1-C ₁₀ H ₇ CH(CO ₂ MgCl)] ⁻ MgX ⁺	I (cold)	1-C ₁₀ H ₇ CH(CO ₂ H) ₂	97
[2-C ₁₀ H ₇ CH(CO ₂ MgCl)] ⁻ MgX ⁺	I (cold)	2-C ₁₀ H ₇ CH(CO ₂ H) ₂	97
C₁₂H₉			
2-C ₆ H ₅ C ₆ H ₄ MgI	?	2-C ₆ H ₅ C ₆ H ₄ C ¹⁴ O ₂ H (60%)	147

* See pp. 914, 947.

TABLE XIII-1 (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₉ (cont.)			
3-C ₆ H ₅ C ₆ H ₄ MgBr	IVa	3-C ₆ H ₅ C ₆ H ₄ CO ₂ H (70% on basis of C ₁₂ H ₉ Br)	198
C₁₂H₁₁			
2-C ₂ H ₅ C ₁₀ H ₆ -1-MgBr	IV	2-C ₂ H ₅ C ₁₀ H ₆ -1-CO ₂ H (76%)	42
2,3-(CH ₃) ₂ C ₁₀ H ₅ -1-MgBr	VI	2,3-(CH ₃) ₂ C ₁₀ H ₅ -1-CO ₂ H (74-83%, crude)	6
4,7-(CH ₃) ₂ C ₁₀ H ₅ -1-MgBr	?	4,7-(CH ₃) ₂ C ₁₀ H ₅ -1-CO ₂ H	14
C₁₂H₁₁O			
6-C ₂ H ₅ OC ₁₀ H ₆ -2-MgBr	IVa	6-C ₂ H ₅ OC ₁₀ H ₆ -2-CO ₂ H (33%)	88
C₁₂H₁₄ClO₂			
[2,4-(CH ₃) ₂ -3-Cl-6-CH ₃ OC ₆ -HCOCHCH ₃] ⁻ MgBr ⁺	VII (2-3 atm.)	2,4-(CH ₃) ₂ -3-Cl-6-CH ₃ OC ₆ HCOCH(CH ₃)CO ₂ H (50%)	3
[2,4-(CH ₃) ₂ -3-Cl-6-C ₂ H ₅ OC ₆ -HCOCH ₂] ⁻ MgBr ⁺	VII (2-3 atm.)	2,4-(CH ₃) ₂ -3-Cl-6-C ₂ H ₅ OC ₆ HCOCH ₂ CO ₂ H (55%)	3
C₁₂H₁₅			
<i>t</i> -C ₄ H ₉ (C ₆ H ₅)C=CHMgBr (in Am ₂ O)	?	<i>cis-t</i> -C ₄ H ₉ (C ₆ H ₅)C=CHCO ₂ H	174
<i>t</i> -C ₄ H ₉ (C ₆ H ₅)C=CHMgBr	1 (0 °)	<i>cis-t</i> -C ₄ H ₉ (C ₆ H ₅)C=CHCO ₂ H (37%); <i>trans-t</i> -C ₄ H ₉ (C ₆ H ₅)C=CHCO ₂ H (4%)	174
4-(CH ₂) ₅ CHC ₆ H ₄ MgBr	I	4-(CH ₂) ₅ CHC ₆ H ₄ CO ₂ H ("poor yield")	20,208
4-(CH ₂) ₅ CHC ₆ H ₄ MgBr	III	4-(CH ₂) ₅ CHC ₆ H ₄ CO ₂ H (70%)	20,49
4-(CH ₂) ₅ CHC ₆ H ₄ MgI	VII	4-(CH ₂) ₅ CHC ₆ H ₄ CO ₂ H (25%)	137
C₁₂H₁₅O			
[2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH(CH ₃)] ⁻ MgBr ⁺	VII	2,4,6-(CH ₃) ₃ C ₆ H ₂ COCH(CH ₃)CO ₂ H	45

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₁₅O₂ [2,4-(CH ₃) ₂ -6-CH ₃ OC ₆ H ₂ - COCHCH ₃]-MgBr ⁺	VII (2-3 atm.)	2,4-(CH ₃) ₂ -6-CH ₃ OC ₆ H ₂ COCH(CH ₃)CO ₂ H (30%)	3
C₁₂H₁₇ 2,4,6-(C ₂ H ₅) ₃ C ₆ H ₂ MgBr	III	2,4,6-(C ₂ H ₅) ₃ C ₆ H ₂ CO ₂ H (66%)	43
C₁₂H₂₅ <i>n</i> -C ₁₂ H ₂₅ MgBr	VII	<i>n</i> -C ₁₂ H ₂₅ CO ₂ H (yielding 55% methyl ester)	217
C₁₃H₉ 9-Fluorenyl-MgBr 9-Fluorenyl-MgBr	I IV + VIII	9-Fluorenenecarboxylic acid 9-Fluorenenecarboxylic acid (18%); fluorene (30%)	76 177
C₁₃H₉O₂ 2-Methoxy-1-dibenzofuryl-MgBr	III	2-Methoxy-1-dibenzofurancarboxylic acid (70%)	64
2-Methoxy-3-dibenzofuryl-MgBr	III	2-Methoxy-3-dibenzofurancarboxylic acid (60%)	64
C₁₃H₁₁ (C ₆ H ₅) ₂ CHCl + Mg	V	(C ₆ H ₅) ₂ CHCO ₂ H (32.5%)	56
C₁₃H₁₁O [2-CH ₃ C ₁₀ H ₆ -1-COCH ₂]-MgBr ⁺	VII (3 atm., <0 °)	2-CH ₃ C ₁₀ H ₆ -1-COCH ₂ CO ₂ H (46%)	2,216

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₁₂NS			
10-Ethyl-3-phenothiazinyl-MgI	IV (?)	10-Ethyl-3-phenothiazinecarboxylic acid (76%)	209
C₁₃H₁₅Br₂O₂			
[2,4,6-(CH ₃) ₃ -3,5-Br ₂ C ₆ COC-(CH ₃) ₂] ⁻ MgBr ⁺	VII	2,4,6-(CH ₃) ₃ -3,5-Br ₂ C ₆ COC(CH ₃) ₂ CO ₂ H	45
C₁₃H₁₆ClO₂			
[2,4-(CH ₃) ₂ -3-Cl-6-C ₂ H ₅ -OC ₆ HCOCHCH ₃] ⁻ MgBr ⁺	VII (2-3 atm.)	2,4-(CH ₃) ₂ -3-Cl-6-C ₂ H ₅ OC ₆ HCOCH(CH ₃)CO ₂ H (41%)	3
C₁₃H₁₇			
4-(CH ₂) ₅ CHC ₆ H ₄ CH ₂ MgCl	I	4-(CH ₂) ₅ CHC ₆ H ₄ CH ₂ CO ₂ H (55%)	20
4-(CH ₂) ₅ CHC ₆ H ₄ CH ₂ MgCl	III	4-(CH ₂) ₅ CHC ₆ H ₄ CH ₂ CO ₂ H (60%)	20
C₁₃H₁₇O			
[2,4,6-(CH ₃) ₃ C ₆ H ₂ COC-(CH ₃) ₂] ⁻ MgBr ⁺	VII	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC(CH ₃) ₂ CO ₂ H (77.4%)	45
C₁₃H₂₅O			
[<i>t</i> -C ₄ H ₉ CH ₂ C(CH ₃)(<i>t</i> -C ₄ H ₉)-COCH ₂] ⁻ MgBr ⁺	I	<i>t</i> -C ₄ H ₉ CH ₂ C(CH ₃)(<i>t</i> -C ₄ H ₉)COCH ₂ CO ₂ H (66%)	195
[(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOCH ₂] ⁻ MgBr ⁺	I	(<i>t</i> -C ₄ H ₉ CH ₂) ₂ CHCOCH ₂ CO ₂ H (49%)	192
C₁₄H₉			
9-Anthryl-MgBr	I (hot)	9-Anthroic acid (72%)	10
9-Phenanthryl-MgBr		9-Phenanthrenecarboxylic acid (70%)	9,164

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₃ 2-C ₆ H ₅ C ₆ H ₄ CH ₂ CH ₂ MgBr (13.5 g. C ₁₄ H ₁₃ Br)	II	2-C ₆ H ₅ C ₆ H ₄ CH ₂ CH ₂ CO ₂ H (5.0 g., 45%)	220
C₁₄H₁₃O [2-CH ₃ C ₁₀ H ₆ -1-COCH(CH ₃)] ⁻ MgBr ⁺	VII (3 atm., <0 °)	2-CH ₃ C ₁₀ H ₆ -1-COCH(CH ₃)CO ₂ H (ca. 46%)	2,216
C₁₄H₂₇O [<i>t</i> -C ₄ H ₉ CH ₂ C(CH ₃)(<i>t</i> -C ₄ H ₉)- COCH(CH ₃)] ⁻ MgBr ⁺	I	<i>t</i> -C ₄ H ₉ CH ₂ C(CH ₃)(<i>t</i> -C ₄ H ₉)COCH(CH ₃)CO ₂ H (48%)	195
C₁₄H₂₉ <i>n</i> -C ₁₄ H ₂₉ MgBr	?	<i>n</i> -C ₁₄ H ₂₉ CO ₂ H	218
C₁₅H₂₉O [<i>t</i> -C ₄ H ₉ CH ₂ C(CH ₃)(<i>t</i> -C ₄ H ₉)- COC(CH ₃) ₂] ⁻ MgBr ⁺	I	<i>t</i> -C ₄ H ₉ CH ₂ C(CH ₃)(<i>t</i> -C ₄ H ₉)COC(CH ₃) ₂ CO ₂ H (37%)	195
C₁₅H₃₁ <i>n</i> -C ₁₅ H ₃₁ MgBr	1a (-20 °)	<i>n</i> -C ₁₅ H ₃₁ C ¹⁴ O ₂ H (yielding 80.4% methyl ester)	31
C₁₅H₃₁O <i>i</i> -C ₆ H ₁₃ CH(CH ₃)CH(CH ₂ CH ₂ O- C ₂ H ₅)CH(CH ₃)MgCl		<i>i</i> -C ₆ H ₁₃ CH(CH ₃)CH(CH ₂ CH ₂ OC ₂ H ₅)- CH(CH ₃)CO ₂ H	37
C₁₆H₁₁O 2,5-Diphenyl-3-furyl-MgBr	I	2,5-Diphenylfuran carboxylic acid (80%)	215
C₁₆H₃₃ <i>n</i> -C ₁₆ H ₃₃ MgI	I	<i>n</i> -C ₁₆ H ₃₃ CO ₂ H	153

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₃₃ (<i>cont.</i>)			
<i>n</i> -C ₁₆ H ₃₃ MgBr	VII	<i>n</i> -C ₁₆ H ₃₃ CO ₂ H (yielding 32% methyl ester)	217
C₁₇H₂₃			
<i>t</i> -C ₄ H ₉ (C ₆ H ₅)(<i>t</i> -C ₄ H ₉ C≡C)CMgBr	?	<i>t</i> -C ₄ H ₉ (C ₆ H ₅)C=C=C(CO ₂ H)- <i>t</i> -C ₄ H ₉	239
C₁₈H₃₇			
<i>n</i> -C ₁₈ H ₃₇ MgBr	I	<i>n</i> -C ₁₈ H ₃₇ CO ₂ H	143, 218
C₁₉H₁₃			
Phenylbiphenylenemethyl-MgBr	I	Phenylbiphenyleneacetic acid (60%)	8
C₁₉H₁₅			
(C ₆ H ₅) ₃ CMgCl	I	(C ₆ H ₅) ₃ CCO ₂ H (83%)	158
(C ₆ H ₅) ₃ CMgBr	?	(C ₆ H ₅) ₃ CCO ₂ H (<i>ca.</i> quant.)	68
C₁₉H₁₉			
<i>t</i> -C ₄ H ₉ C≡C(C ₆ H ₅) ₂ CMgBr	II	<i>t</i> -C ₄ H ₉ C≡C(C ₆ H ₅) ₂ CCO ₂ H (34%, crude)	169
C₁₉H₂₇			
(<i>t</i> -C ₄ H ₉ C≡C) ₃ CMgBr	II	(<i>t</i> -C ₄ H ₉ C≡C) ₃ CCO ₂ H	241
C₂₀H₁₃			
10-Phenyl-9-anthryl-MgBr	I	10-Phenyl-9-anthracenecarboxylic acid (40%)	35
α-Phenyl-β-biphenylenevinyl-MgBr	I	α-Phenyl-β-biphenyleneacrylic acid	110
C₂₀H₁₄Cl			
4-ClC ₆ H ₄ (C ₆ H ₅)C=C(C ₆ H ₅)MgBr	I	<i>cis</i> - and <i>trans</i> -4-ClC ₆ H ₄ (C ₆ H ₅)C=C(C ₆ H ₅)CO ₂ H	109

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₀H₁₅			
(C ₆ H ₅) ₂ C=C(C ₆ H ₅)MgBr	I	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)CO ₂ H (94%)	108
C₂₁H₁₅			
(1-C ₁₀ H ₇) ₂ CHMgCl	V	(1-C ₁₀ H ₇) ₂ CHCO ₂ H (57%)	161
(2-C ₁₀ H ₇) ₂ CHMgCl	V	(2-C ₁₀ H ₇) ₂ CH ₂ CO ₂ H (36%)	160
C₂₁H₁₇			
C ₆ H ₅ (4-CH ₃ C ₆ H ₄)C=C(C ₆ H ₅)MgBr	I	<i>cis</i> -C ₆ H ₅ (4-CH ₃ C ₆ H ₄)C=C(C ₆ H ₅)CO ₂ H	109
C₂₁H₁₇O			
C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)C=C(C ₆ H ₅)MgBr	I	<i>cis</i> - and <i>trans</i> -C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)C=C(C ₆ H ₅)CO ₂ H	109
C₂₂H₁₉			
(4-CH ₃ C ₆ H ₄) ₂ C=C(C ₆ H ₅)MgBr	I	(4-CH ₃ C ₆ H ₄) ₂ C=C(C ₆ H ₅)CO ₂ H	109
C₂₂H₁₉O₂			
(4-CH ₃ OC ₆ H ₄) ₂ C=C(C ₆ H ₅)MgBr	I	(4-CH ₃ OC ₆ H ₄) ₂ C=C(C ₆ H ₅)CO ₂ H	109
C₂₂H₂₁			
(4-CH ₃ C ₆ H ₄) ₃ CMgCl	I (hot)	(4-CH ₃ C ₆ H ₄) ₃ CCO ₂ H ("very poor yield")	159
C₂₂H₄₅			
<i>n</i> -C ₂₂ H ₄₅ MgBr	?	<i>n</i> -C ₂₂ H ₄₅ CO ₂ H	218
C₂₄H₁₇			
2,4,6-(C ₆ H ₅) ₃ C ₆ H ₂ MgBr	I	2,4,6-(C ₆ H ₅) ₃ C ₆ H ₂ CO ₂ H (84.1%)	112

* See pp. 914, 947.

TABLE XIII-I (Continued)

<u>RMgX</u>	<u>Method *</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₆H₁₆			
C ₂₆ H ₁₆ (MgBr) ₂ (from 9,10-bis- <i>p</i> -bromophenylanthracene)	I (-15 °)	9,10-Bis-(4-carboxyphenyl)anthracene (50%)	34
C₂₇H₄₅			
3-Cholesteryl-MgCl	II (0 °)	5-Cholestene-3-carboxylic acid	123
3-Cholesteryl-MgCl	IVa	5-Cholestene-3-carboxylic acid (85%)	11

* See p. 914.

REFERENCES FOR TABLE XIII-I

- (1) Acree, *Ber.*, 37, 265-8 (1904).
- (2) Adams and Binder, *J. Am. Chem. Soc.*, 63, 2773-6 (1941).
- (3) Adams and Gross, *J. Am. Chem. Soc.*, 64, 1786-90 (1942).
- (4) Adams and Ludington, *J. Am. Chem. Soc.*, 67, 794-7 (1945).
- (5) Arnold, Bank, and Liggett, *J. Am. Chem. Soc.*, 63, 3444-6 (1941).
- (6) Arnold and Liggett, *J. Am. Chem. Soc.*, 64, 2875-7 (1942).
- (7) Austin and Johnson, *J. Am. Chem. Soc.*, 54, 647-60 (1932).
- (8) Bachmann, *J. Am. Chem. Soc.*, 52, 3287-90 (1930).
- (9) Bachmann, *J. Am. Chem. Soc.*, 56, 1363-7 (1934).
- (10) Bachmann and Kloetzel, *J. Org. Chem.*, 3, 55-61 (1938).
- (11) Baker and Squire, *J. Am. Chem. Soc.*, 70, 1487-90 (1948).
- (12) Barbier and Grignard, *Compt. rend.*, 145, 255-7 (1907); *Chem. Abstr.*, 1, 2797 (1907).
- (13) Barnes, *Organic Syntheses*, 21, 77-9 (1941).
- (14) Barnett and Cook, *J. Chem. Soc.*, 1933, 22-4.
- (15) Blicke, *J. Am. Chem. Soc.*, 49, 2843-9 (1927).
- (16) Bodroux, *Compt. rend.*, 137, 710-2 (1903); *J. Chem. Soc.*, 86,1, 64 (1904).
- (17) Bodroux, *Compt. rend.*, 136, 617-8 (1903); *J. Chem. Soc.*, 84,1, 420 (1903).
- (18) Bodroux, *Bull. soc. chim.*, [3], 31, 24-30 (1904).
- (19) Bodroux, *Bull. soc. chim.*, [3], 31, 30-33 (1904).
- (20) Bodroux and Thomassin, *Bull. soc. chim.*, [5], 6, 1411-6 (1939).
- (21) Bogert and Tuttle, *J. Am. Chem. Soc.*, 38, 1349-68 (1916).
- (22) Borsche and Menz, *Ber.*, 41, 190-210 (1908).
- (23) Bouveault, *Bull. soc. chim.*, [3], 29, 1051-4 (1903).
- (24) Bouveault, *Compt. rend.*, 138, 1108-10 (1904); *J. Chem. Soc.*, 86,1, 546 (1904).
- (25) Carothers and Berchet, *J. Am. Chem. Soc.*, 55, 1094-6 (1933).
- (26) Challenger, Clapham, and Emmott, *J. Inst. Petroleum*, 34, 922-9 (1948); *Chem. Abstr.*, 43, 4666 (1949).
- (27) Clément, *Compt. rend.*, 198, 655-7 (1937).
- (28) Clément, *Ann. chim.*, [11], 13, 243-316 (1940).
- (29) Courtot and Tchelitcheff, *Compt. rend.*, 217, 201-3 (1943); *Chem. Abstr.*, 38, 5502 (1944).
- (30) Dauben, *J. Org. Chem.*, 13, 313-6 (1948).
- (31) Dauben, *J. Am. Chem. Soc.*, 70, 1376-8 (1948).
- (32) Dauben, Reid, and Yankwich, *Anal. Chem.*, 19, 828-32 (1947).
- (33) Denisenko, *J. Gen. Chem. (U.S.S.R.)*, 18, 219-21 (1948); *Chem. Abstr.*, 42, 6744 (1948).
- (34) Dufraisse and Margoulis-Molho, *Bull. soc. chim.*, [5], 7, 930-3 (1940).
- (35) Dufraisse, Velluz, and Velluz, *Bull. soc. chim.*, [5], 4, 1260-4 (1937).
- (36) Dupont, *Compt. rend.*, 148, 1522-4 (1909); *Chem. Abstr.*, 3, 2674 (1909); *Chem. Zentr.*, 1909,II, 181.
- (37) Dutta, *Science and Culture*, 7, 316-7 (1941); *Chem. Abstr.*, 36, 3156 (1942).
- (38) Fields, Leafer, and Rohan, *Science*, 109, 35 (1949); *Chem. Abstr.*, 43, 9045 (1949).
- (39) Fieser, Holmes, and Newman, *J. Am. Chem. Soc.*, 58, 1055 (1936).
- (40) Fieser and Riegel, *J. Am. Chem. Soc.*, 59, 2561-5 (1937).
- (41) Fries and Schimmelschmidt, *Ber.*, 58B, 2835-45 (1925).
- (42) Fuson and Chadwick, *J. Org. Chem.*, 13, 484-8 (1948).
- (43) Fuson and Corse, *J. Am. Chem. Soc.*, 60, 2063-6 (1938).
- (44) Fuson, Corse, and Welldon, *J. Am. Chem. Soc.*, 63, 2645-8 (1941).
- (45) Fuson, Fugate, and Fisher, *J. Am. Chem. Soc.*, 61, 2362-5 (1939).

- (46) Fuson, McKeever, and Behr, *J. Am. Chem. Soc.*, 63, 2648-9 (1941).
- (47) Fuson, McKusick, and Mills, *J. Org. Chem.*, 11, 60-6 (1946).
- (48) Fuson, Mills, Klose, and Carpenter, *J. Org. Chem.*, 12, 587-95 (1947).
- (49) Fuson and Tull, *J. Am. Chem. Soc.*, 71, 2543-6 (1949).
- (50) Gilman and Dickey, *J. Am. Chem. Soc.*, 52, 2144-7 (1930).
- (51) Gilman and Harris, *J. Am. Chem. Soc.*, 49, 1825-8 (1927).
- (52) Gilman and Harris, *J. Am. Chem. Soc.*, 53, 3541-6 (1931).
- (53) Gilman and Harris, *Rec. trav. chim.*, 50, 1050-5 (1931).
- (54) Gilman and Heck, *Ber.*, 62B, 1379-84 (1929).
- (55) Gilman and Kirby, *Organic Syntheses*, 5, 75-7 (1925).
- (56) Gilman and Kirby, *J. Am. Chem. Soc.*, 48, 1733-6 (1926).
- (57) Gilman and Kirby, *J. Am. Chem. Soc.*, 51, 3475-8 (1929).
- (58) Gilman and Kirby, *Organic Syntheses*, Coll. Vol. I, 2nd ed., pp. 361-4, 1941.
- (59) Gilman and McGlumphy, *Bull. soc. chim.*, [4], 43, 1322-8 (1928).
- (60) Gilman and Parker, *J. Am. Chem. Soc.*, 46, 2816-22 (1924).
- (61) Gilman and St. John, *Rec. trav. chim.*, 48, 743-4 (1929).
- (62) Gilman and St. John, *Rec. trav. chim.*, 49, 1172-7 (1930).
- (63) Gilman, St. John, and Schulze, *Organic Syntheses*, Coll. Vol. II, pp. 425-7, 1943.
- (64) Gilman and Van Ess, *J. Am. Chem. Soc.*, 61, 1365-71 (1939).
- (65) Gilman and Zoellner, *J. Am. Chem. Soc.*, 50, 425-8 (1928).
- (66) Gilman and Zoellner, *Rec. trav. chim.*, 47, 1058-63 (1928).
- (67) Gilman and Zoellner, *Bull. soc. chim.*, [4], 49, 7-9 (1931).
- (68) Gomberg and Bachmann, *J. Am. Chem. Soc.*, 52, 2455-61 (1930).
- (69) Grard, *Compt. rend.*, 189, 541-3 (1929).
- (70) Greenwood, Whitmore, and Crooks, *J. Am. Chem. Soc.*, 60, 2028-30 (1938).
- (71) Grignard, *Ann. Univ. Lyon, N.S.*, 6, 1-116 (1901); *Chem. Zentr.*, 1901, II, 622.
- (72) Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).
- (73) Grignard, *Compt. rend.*, 138, 1048-50 (1904); *J. Chem. Soc.*, 86, I, 494 (1904).
- (74) Grignard, *Compt. rend.*, 198, 2217-20 (1934).
- (75) Grignard and Courtot, *Compt. rend.*, 152, 272-4 (1911); *Chem. Zentr.*, 1911, I, 885.
- (76) Grignard and Courtot, *Compt. rend.*, 152, 1493-5 (1911); *Chem. Abstr.*, 5, 3409 (1911); *Chem. Zentr.*, 1911, II, 148.
- (77) Grignard, Lepayre, and Tch  oufaki, *Compt. rend.*, 187, 517-20 (1928).
- (78) Grignard and Vignon, *Compt. rend.*, 144, 1358-60 (1907); *Chem. Zentr.*, 1907, II, 681.
- (79) Grosse and Weinhouse, *Science*, 104, 402-3 (1946); *Chem. Abstr.*, 41, 2009 (1947).
- (80) Gutt, *Ber.*, 40, 2061-70 (1907).
- (81) Harwood and Ralston, *J. Org. Chem.*, 12, 740-1 (1947).
- (82) Haynes and Jones, *Nature*, 155, 730 (1945).
- (83) Heidelberger, Brewer, and Dauben, *J. Am. Chem. Soc.*, 69, 1389-91 (1947).
- (84) Heilbron, Jones, and Sondheimer, *J. Chem. Soc.*, 1947, 1586-90.
- (85) Houben, *Ber.*, 36, 2897-900 (1903).
- (86) Houben, *Ber.*, 38, 3796-801 (1905).
- (87) Houben and Kesselkaul, *Ber.*, 35, 2519-23 (1902).
- (88) Hudson, *J. Chem. Soc.*, 1946, 76-8.
- (89) Hurd and Wilkinson, *J. Am. Chem. Soc.*, 70, 739-41 (1948).
- (90) Hussey, *J. Am. Chem. Soc.*, 73, 1364-5 (1951).
- (91) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 34, 242-4 (1902); *Bull. soc. chim.*, [3], 30, 210 (1903).

- (92) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 35, 431-2 (1903); *Bull. soc. chim.*, [3], 32, 552 (1904).
- (93) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 35, 1269-75 (1903); *Bull. soc. chim.*, [3], 34, 181 (1905).
- (94) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 36, 8-9 (1904); *Bull. soc. chim.*, [3], 34, 204 (1905).
- (95) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 36, 1545-51 (1904); *Bull. soc. chim.*, [3], 36, 177 (1906).
- (96) Ivanoff, *Bull. soc. chim.*, [4], 37, 287-96 (1925).
- (97) Ivanoff and Pchénitchny, *Bull. soc. chim.*, [5], 1, 223-33 (1934).
- (98) Ivanoff and Pchénitchny, *Bull. soc. chim.*, [5], 1, 233-5 (1934).
- (99) Ivanoff and Spasoff, *Bull. soc. chim.*, [4], 49, 19-23 (1931).
- (100) Jacobi, *J. prakt. Chem.*, [2], 129, 55-96 (1931).
- (101) Jacobs, Cramer, and Weiss, *J. Am. Chem. Soc.*, 62, 1849-54 (1940).
- (102) Jacobs, Winstein, Henderson, Bond, Ralls, Seymour, and Florsheim, *J. Org. Chem.*, 11, 229-38 (1946).
- (103) Jacoby, Hayes, and Van Ess, *Proc. Iowa Acad. Sci.*, 43, 204-5 (1936); *Chem. Abstr.*, 32, 4160 (1938).
- (104) Jezierski, *Roczniki Chem.*, 20, 47-53 (1946); *Chem. Abstr.*, 42, 1910 (1948).
- (105) Jones, *J. Am. Chem. Soc.*, 69, 2346-50 (1947).
- (106) Kauffmann, *Ber.*, 45, 2333-7 (1912).
- (107) Kharasch, Lambert, and Urry, *J. Org. Chem.*, 10, 298-306 (1945).
- (108) Koelsch, *J. Am. Chem. Soc.*, 54, 2045-8 (1932).
- (109) Koelsch, *J. Am. Chem. Soc.*, 54, 2487-93 (1932).
- (110) Koelsch, *J. Am. Chem. Soc.*, 54, 3384-9 (1932).
- (111) Kohler and Baltzly, *J. Am. Chem. Soc.*, 54, 4015-26 (1932).
- (112) Kohler and Blanchard, *J. Am. Chem. Soc.*, 57, 367-71 (1935).
- (113) Lane, Roberts, and Young, *J. Am. Chem. Soc.*, 66, 543-5 (1944).
- (114) Lespieau, *Compt. rend.*, 157, 1439-40 (1913); *Chem. Zentr.*, 1914, 1, 339.
- (115) Lespieau, *Bull. soc. chim.*, [4], 43, 1189-93 (1928).
- (116) Lester and Bailey, *J. Am. Chem. Soc.*, 68, 375-6 (1946).
- (117) Levene and Marker, *J. Biol. Chem.*, 93, 749-74 (1931).
- (118) Levene and Marker, *J. Biol. Chem.*, 110, 299-309 (1935).
- (119) Levene and Marker, *J. Biol. Chem.*, 110, 329-42 (1935).
- (120) Majima and Kotake, *Ber.*, 55B, 3859-72 (1922).
- (121) Malmgren, *Ber.*, 36, 2608-42 (1903).
- (122) Manske and Ledingham, *Can. J. Research*, 27, 158-60 (1949).
- (123) Marker, Oakwood, and Crooks, *J. Am. Chem. Soc.*, 58, 481-3 (1936).
- (124) Marvel, Blomquist, and Vaughn, *J. Am. Chem. Soc.*, 50, 2810-2 (1928).
- (125) Mayer, Schafer, and Rosenblack, *Arch. Pharm.*, 267, 571-84 (1929); *Chem. Zentr.*, 1929, 11, 3009.
- (126) McBee and Truchan, *J. Am. Chem. Soc.*, 70, 2910-1 (1948).
- (127) Meerwein, *Ann.*, 417, 255-77 (1918).
- (128) Meyer and Tögel, *Ann.*, 347, 55-70 (1906).
- (129) Mikhant'ev, *J. Gen. Chem. (U.S.S.R.)*, 15, 641-2 (1945); *Chem. Abstr.*, 40, 5697 (1946).
- (130) Mousseron and Granger, *Bull. soc. chim.*, [5], 13, 251-6 (1946).
- (131) Mousseron, Granger, Bourrel, Cellier, Jullien, Canals, and Cabanes, *Bull. soc. chim.*, [5], 14, 605-15 (1947).
- (132) Mousseron and Winternitz, *Bull. soc. chim.*, [5], 12, 70-1 (1945).
- (133) Nametkin and Gabriadze, *J. Gen. Chem. (U.S.S.R.)*, 13, 560-8 (1943); *Chem. Abstr.*, 39, 1142 (1945).
- (134) Nametkin and Volodina, *J. Gen. Chem. (U.S.S.R.)*, 17, 325-34 (1947); *Chem. Abstr.*, 42, 527 (1948).

- (135) Nesmeyanov and Pecherskaya, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1943, 317-8; *Chem. Abstr.*, 38, 5492 (1944).
- (136) Neunhoeffer, *Ann.*, 509, 115-30 (1934).
- (137) Neunhoeffer, *Ann.*, 526, 58-65 (1936).
- (138) Neunhoeffer and Schlüter, *Ann.*, 526, 65-71 (1936).
- (139) Oddo, *Gazz. chim. ital.*, 39, I, 649-59 (1909); *Chem. Zentr.*, 1909, II, 914.
- (140) Oddo, *Gazz. chim. ital.*, 42, I, 346-52 (1912); *Chem. Abstr.*, 6, 2234 (1912).
- (141) Oddo and Moschini, *Gazz. chim. ital.*, 42, II, 244-56 (1912); *Chem. Abstr.*, 6, 3425 (1912).
- (142) Oddo and Sessa, *Gazz. chim. ital.*, 41, I, 234-48 (1911); *Chem. Abstr.*, 5, 2638 (1911).
- (143) Oskerk, *J. Russ. Phys.-Chem. Soc.*, 46, 411-6 (1914); *Chem. Abstr.*, 8, 3185 (1914).
- (144) Porter and Suter, *J. Am. Chem. Soc.*, 57, 2022-6 (1935).
- (145) Puntambeker and Zoellner, *Organic Syntheses*, Coll. Vol. I, 2nd ed., pp. 524-6, 1941.
- (146) Quelet, *Bull. soc. chim.*, [4], 45, 255-74 (1929).
- (147) Ray and Geiser, *Science*, 109, 200 (1949); *Chem. Abstr.*, 43, 3917 (1949).
- (148) Rivière, *Ann. chim.*, [12], 1, 157-231 (1946).
- (149) Roberts and Young, *J. Am. Chem. Soc.*, 67, 148-50 (1945).
- (150) Ruben, Allen, and Nahinsky, *J. Am. Soc.*, 64, 3050 (1942).
- (151) Rupe and Hirschmann, *Helv. Chim. Acta*, 11, 1180-200 (1928).
- (152) Rupe and Proske, *Ber.*, 43, 1231-4 (1910).
- (153) Ruttan, *Original Commun.*, 8th Int. Congr. Appl. Chem., 25, 431-42 (1913); *Chem. Zentr.*, 1913, I, 2108.
- (154) Sabatier and Mailhe, *Ann. chim.*, [8], 10, 527-71 (1907).
- (155) Salkind, *Ber.*, 67B, 1031-6 (1934).
- (156) Savard and Hösögüt, *Rev. faculte sci. univ. Istanbul*, [N.S.], 3, 164-73 (1938); *Chem. Abstr.*, 32, 5795 (1938).
- (157) Schlenk and Ochs, *Ber.*, 48, 676-80 (1915).
- (158) Schmidlin, *Ber.*, 39, 628-36 (1906).
- (159) Schmidlin and Hodgson, *Ber.*, 41, 438-47 (1908).
- (160) Schmidlin and Huber, *Ber.*, 43, 2824-37 (1910).
- (161) Schmidlin and Massini, *Ber.*, 42, 2377-92 (1909).
- (162) Schroeter, *Ber.*, 40, 1584-5 (1907).
- (163) Shepard, Winslow, and Johnson, *J. Am. Chem. Soc.*, 52, 2083-90 (1930).
- (164) Shoppee, *J. Chem. Soc.*, 1933, 37-45.
- (165) Smith and Byrkit, *J. Am. Chem. Soc.*, 55, 4305-8 (1933).
- (166) Snyder, Weaver, and Marshall, *J. Am. Chem. Soc.*, 71, 289-91 (1949).
- (167) Sommer, Gold, Goldberg, and Marans, *J. Am. Chem. Soc.*, 71, 1509 (1949).
- (168) Spaeth, Geissman, and Jacobs, *J. Org. Chem.*, 11, 399-404 (1946).
- (169) Stampfli and Marvel, *J. Am. Chem. Soc.*, 53, 4057-63 (1931).
- (170) Steinkopf, Poulsson, and Herdey, *Ann.*, 536, 128-34 (1938).
- (171) Straus, Kollek, and Hauptmann, *Ber.*, 63B, 1886-99 (1930).
- (172) Thorp and Kamm, *J. Am. Chem. Soc.*, 36, 1022-8 (1914).
- (173) Tiffeneau, *Compt. rend.*, 135, 1346-8 (1902); *J. Chem. Soc.*, 84, I, 241 (1903); *Chem. Zentr.*, 1903, I, 328.
- (174) Tsatsas, *Compt. rend.*, 220, 662-4 (1945); *Chem. Abstr.*, 40, 4699 (1946).
- (175) Tsatsas, *Ann. chim.*, [12], 1, 342-94 (1946).
- (176) Tschitschibabin, *J. Russ. Phys.-Chem. Soc.*, 45, 184-8 (1913); *Chem. Zentr.*, 1913, I, 2028.
- (177) Tucker and Whalley, *J. Chem. Soc.*, 1949, 50-5.
- (178) Tuot, *Compt. rend.*, 208, 1026-8 (1939); *Chem. Abstr.*, 33, 6794 (1939).
- (179) Umnova, *J. Russ. Phys.-Chem. Soc.*, 44, 1395-406 (1912); *Chem. Zentr.*, 1913, I, 1402.

- (180) Vavon and Rivière, *Compt. rend.*, 213, 1016-8 (1941).
(181) Vavon and Rivière, *Compt. rend.*, 220, 286-8 (1945).
(182) von Braun and Deutsch, *Ber.*, 44, 3699-706 (1911).
(183) von Braun and Kirschbaum, *Ber.*, 44, 1039-48 (1911).
(184) von Braun and Kirschbaum, *Ber.*, 52B, 1713-6 (1919).
(185) von Braun and Kühn, *Ber.*, 58B, 2168-73 (1925).
(186) von Braun and Kühn, *Ber.*, 60B, 2557-66 (1927).
(187) von Braun and Sobecki, *Ber.*, 44, 1918-31 (1911).
(188) Whitmore, *Rec. trav. chim.*, 57, 562-8 (1938).
(189) Whitmore and Badertscher, *J. Am. Chem. Soc.*, 55, 1559-67 (1933).
(190) Whitmore and Forster, *J. Am. Chem. Soc.*, 64, 2966-8 (1942).
(191) Whitmore and Fox, *J. Am. Chem. Soc.*, 51, 3363-7 (1929).
(192) Whitmore and Lester, *J. Am. Chem. Soc.*, 64, 1251-3 (1942).
(193) Whitmore and Lewis, *J. Am. Chem. Soc.*, 64, 1618-9 (1942).
(194) Whitmore, Marker, and Plambeck, *J. Am. Chem. Soc.*, 63, 1626-30 (1941).
(195) Whitmore and Randall, *J. Am. Chem. Soc.*, 64, 1242-6 (1942).
(196) Whitmore and Sloat, *J. Am. Chem. Soc.*, 64, 2968-70 (1942).
(197) Whitmore, Whitaker, Mosher, Breivik, Wheeler, Miner, Sutherland, Wagner, Clapper, Lewis, Lux, and Popkin, *J. Am. Chem. Soc.*, 63, 643-54 (1941).
(198) Woods and Reed, *J. Am. Chem. Soc.*, 71, 1348-50 (1949).
(199) Zelinsky, *Ber.*, 35, 2687-92 (1902).
(200) Zelinsky, *Ber.*, 35, 2692-4 (1902).
(201) Zelinsky, *Ber.*, 35, 4415-9 (1902).
(202) Zelinsky, *Ber.*, 36, 208-9 (1903).
(203) Zelinsky, *Ber.*, 41, 2627-8 (1908).
(204) Zelinsky and Gutt, *Ber.*, 40, 3049-50 (1907).
(205) Letsinger and Schnizer, *J. Org. Chem.*, 16, 704-7 (1951).
(206) Moser and Sause, *J. Org. Chem.*, 15, 631-3 (1950).
(207) Whitmore, Wheeler, and Surmatis, *J. Am. Chem. Soc.*, 63, 3237 (1941).
(208) Truffault, *Compt. rend.*, 207, 676-8 (1938); *Chem. Abstr.*, 33, 2886 (1939).
(209) Gilman, Van Ess, and Shirley, *J. Am. Chem. Soc.*, 66, 1214-6 (1944).
(210) Grignard, Lepayre, and Tchéoufaki, *Bull. soc. chim.*, [4], 43, 931-2 (1928).
(211) Gard, *Ann. chim.*, [10], 13, 336-81 (1930).
(212) Meerwein, *Ann.*, 405, 129-75 (1914).
(213) Letsinger and Schnizer, *J. Org. Chem.*, 16, 704-7 (1951).
(214) Newman, *J. Am. Chem. Soc.*, 62, 2295-300 (1940).
(215) Lutz and Smith, *J. Am. Chem. Soc.*, 63, 1148-50 (1941).
(216) Adams and Binder, *J. Am. Chem. Soc.*, 63, 1459-60 (1941).
(217) Cason and Winans, *J. Org. Chem.*, 15, 139-47 (1950).
(218) Smith and Fuzek, *J. Am. Chem. Soc.*, 72, 3454-8 (1950).
(219) Hiers and Adams, *J. Am. Chem. Soc.*, 48, 2385-95 (1926).
(220) Dice, Watkins, and Schuman, *J. Am. Chem. Soc.*, 72, 1738-40 (1950).
(221) Wotiz, Matthews, and Lieb, *J. Am. Chem. Soc.*, 73, 5503-4 (1951).
(222) Prevost, Gaudemar, and Honigberg, *Compt. rend.*, 230, 1186-8 (1950); *Chem. Abstr.*, 45, 1497 (1951).
(223) Steinkopf and Schmitt, *Ann.*, 533, 264-9 (1938).
(224) Sherman and Amstutz, *J. Am. Chem. Soc.*, 72, 2195-9 (1950).
(225) Gaertner, *J. Am. Chem. Soc.*, 72, 4326-7 (1950).
(226) Gaertner, *J. Am. Chem. Soc.*, 73, 3934-7 (1951).
(227) Campaigne and LeSuer, *J. Am. Chem. Soc.*, 70, 1555-8 (1948).
(228) Lecocq and Buu-Hoï, *Compt. rend.*, 224, 658-9 (1947); *Chem. Abstr.*, 41, 4791 (1947).
(229) Wotiz, *J. Am. Chem. Soc.*, 72, 1639-42 (1950).
(230) Davis and Marvel, *J. Am. Chem. Soc.*, 53, 3840-51 (1931).
(231) Mousseron and Du, *Bull. soc. chim.*, [5], 15, 91-6 (1948).

- (232) Gilman and Webb, *J. Am. Chem. Soc.*, 71, 4062-6 (1949).
(233) Challenger and Miller, *J. Chem. Soc.*, 1938, 849-9.
(234) Wotiz and Palchak, *J. Am. Chem. Soc.*, 73, 1971-2 (1951).
(235) Bateman, Cunneen, and Koch, *Nature*, 164, 242 (1949).
(236) Lappin, *J. Am. Chem. Soc.*, 71, 3966-8 (1949).
(237) Gaertner, *J. Am. Chem. Soc.*, 74, 766-7 (1952).
(238) Gaertner, *J. Am. Chem. Soc.*, 74, 2185-8 (1952).
(239) Ford, Thompson, and Marvel, *J. Am. Chem. Soc.*, 57, 2619-23 (1933).
(240) Gilman and Haubein, *J. Am. Chem. Soc.*, 67, 1033-4 (1945).
(241) Salzberg and Marvel, *J. Am. Chem. Soc.*, 50, 1737-44 (1928).

Method V. The method of Houben²³ (reminiscent of the Barbier synthesis of alcohols), in which an alkyl halide is gradually added to magnesium covered with ether while carbon dioxide is passed into the ether.

Method VI. The method of Arnold,²⁴ whereby a Grignard reagent solution is slowly dropped into ether through which carbon dioxide is passed.

Method VIa. The method of Gilman,²⁵ whereby a Grignard reagent solution is sprayed into an atmosphere of carbon dioxide.

Method VII. The method of Bogert,²⁶ in which a Grignard reagent solution is treated with carbon dioxide under pressure, with provisions for cooling if necessary.

Method VIII. The method of Oddo,²⁷ in which an ether-free Grignard reagent is heated ($>250^{\circ}$) in a stream of carbon dioxide.

Miscellaneous methods (IX), including that of Heilbron *et al.*^{27.1}, in which the Grignard reagent is combined with a benzene-solid carbon dioxide suspension in an autoclave, which is then sealed and is allowed to stand at room temperature for about a day (*i.e.*, twenty-two hours).

Miscellaneous uses of the carbonation reaction. In addition to its preparative use, which is summarized in Table XIII-I, the carbonation reaction has been used for various diagnostic purposes. For example, Spencer and Stokes²⁸ have used it to demonstrate the preparation of a Grignard reagent from iodobenzene and magnesium without the aid of ether. Their method, differing somewhat from any of those heretofore described, consisted in triturating the Grignard reagent in a mortar with solid carbon dioxide and a little added ether.

Carbonation has also served to furnish a rough estimate of yields in Grignard reagent preparations (see Chapter II. The Preparation of Grignard Reagents, Table II-VI.) for which purpose it is obviously ill-adapted to general use.

²³ Houben, *Ber.*, 36, 2897-900 (1903).

²⁴ Arnold, Bank, and Liggett, *J. Am. Chem. Soc.*, 63, 3444-6 (1941).

²⁵ Gilman and Parker, *J. Am. Chem. Soc.*, 46, 2816-22 (1924).

²⁶ Bogert and Tuttle, *J. Am. Chem. Soc.*, 38, 1349-68 (1916).

²⁷ Oddo and Moschini, *Gazz. chim. ital.*, 42, 11, 244-56 (1912); *Chem. Abstr.*, 6, 3425 (1912).

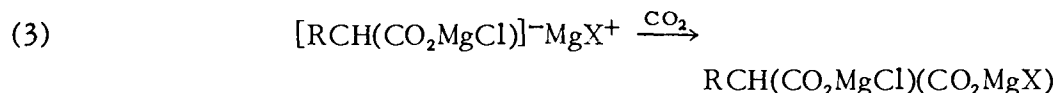
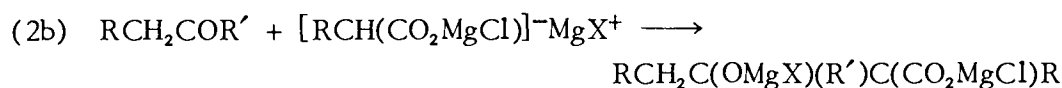
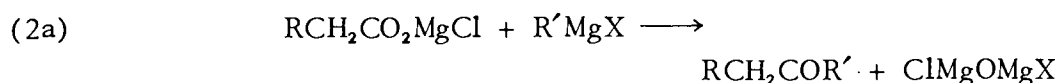
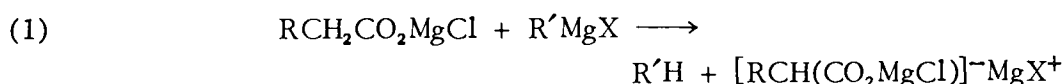
^{27.1} Heilbron, Jones, and Sondheimer, *J. Chem. Soc.*, 1947, 1586-90.

²⁸ Spencer and Stokes, *J. Chem. Soc.*, 93, 68-72 (1908).

Gilman and Jones²⁹ have employed the carbonation reaction to investigate the possibility of functional exchange (*q.v.*, Chapter XVI) between organomagnesium halides and organic halides, as have Kharasch and Fuchs.³⁰

St. John and St. John³¹ have carbonated the mixtures of Grignard reagents resulting from the treatment of magnesium with mixtures of organic halides, and have so arrived at a rough estimate of the relative reactivities of various halides toward magnesium.

Ivanoff *et al.*³² have employed carbonation to determine to what extent phenylacetic and related acids undergo reaction 1, to form a Grignard reagent (or enolate³³), as distinguished from the "normal" reaction 2a. The products of reaction 1 undergo reaction 3 to form phenylmalonic or related acids.



Taking advantage of the relative rates of carbonation of bornyl- and isobornylmagnesium chlorides, Rivière³⁴ has employed partial carbonation (*ca.* 66 percent) to remove bornylmagnesium chloride from the mixture of Grignard reagents prepared from pinene hydrochloride, leaving nearly pure isobornylmagnesium chloride.

It is now well-known that there are definite limitations on the use of carbonation as a means toward determination of structure. For instance carbonation cannot be depended upon to distinguish between halomagnesium enolates and true organomagnesium compounds.³⁵ Several enolate carbonations are recorded in Table XIII-I. Other limitations of the method are discussed in Chapter XVII. Allylic Rearrangements (*q.v.*).

CARBOXYLIC ACIDS AND THEIR SALTS

As was noted in the preceding discussion of carbon dioxide reactions, Grignard (*loc. cit.*¹⁵) observed that the carboxylates initially formed

²⁹ Gilman and Jones, *J. Am. Chem. Soc.*, 51, 2840-3 (1929).

³⁰ Kharasch and Fuchs, *J. Org. Chem.*, 10, 292-7 (1945).

³¹ St. John and St. John, *Rec. trav. chim.*, 55, 585-8 (1936).

³² Ivanoff and Spassoff, *Bull. soc. chim.*, [4], 49, 19-23, 371-5 (1931); Ivanoff and Pchénitchny, *ibid.*, [5], 1, 223-33, 233-5 (1934).

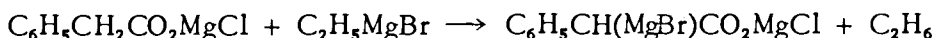
³³ See: Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931).

³⁴ Rivière, *Ann. chim.*, [12], 1, 157-231 (1946).

³⁵ See, *e.g.*, Kohler and Tishler, *J. Am. Chem. Soc.*, 54, 1594-600 (1932).

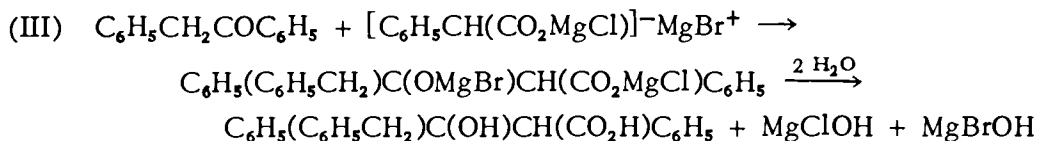
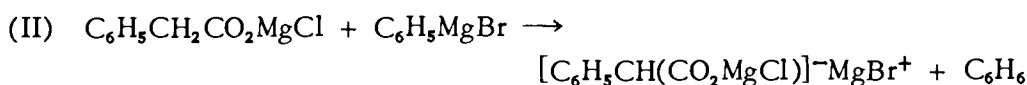
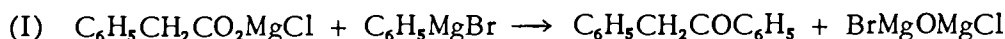
undergo further successive reactions with Grignard reagents to form ketone complexes and tertiary alcoholates. The available data indicate that only in very special cases have these reactions any preparative potentialities. In general the esters may be expected to furnish better yields of tertiary alcohols than the corresponding acids, whereas the acid chlorides may be expected to furnish superior yields of ketones, particularly if one of the special techniques, such as low-temperature operation or cadmium chloride addition, is employed. Perhaps for this reason, the reactions of carboxylic acids and their salts with Grignard reagents have been the object of relatively little study and practically no theoretical investigation. Representative data are collected in Table XIII-II.

Of special interest, however, are the reactions of phenylacetic and related acids (or their salts) with Grignard reagents. Grignard³⁶ observed that when an ethereal solution of ethylmagnesium bromide (1.5 equivalent) is added to an ethereal suspension of chloromagnesium phenylacetate at 0° an "active hydrogen" displacement occurs with the liberation of ethane.



Schlenk *et al.*³⁷ suggest that this reaction should be regarded as a special case of enolization (*q.v.*), and there is much to recommend that point of view, for the resulting magnesium compound behaves in practically all respects like the enolate of acetomesitylene, as the extensive studies of Ivanoff *et al.*³⁸ have shown.

However, as Ivanoff *et al.* have demonstrated, the enolization reaction is, for some Grignard reagents, at least, competitive with "normal" ketone formation. From reactions of phenyl-, *p*-bromophenyl-, *m*-tolyl- and *p*-tolylmagnesium bromides with chloromagnesium phenylacetate, Ivanoff and Spassoff (*loc. cit.*^{38b}) have isolated products which must result from condensation of enolate with ketone.



³⁶ Grignard, *Bull. soc. chim.*, [3], 31, 751-7 (1904).

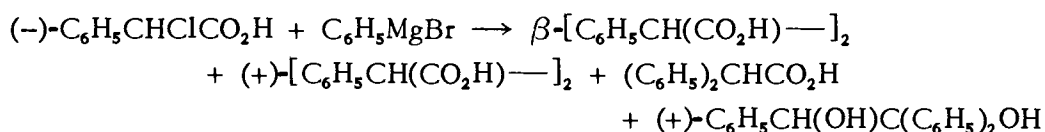
³⁷ Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931).

³⁸ Ivanoff and Spassoff, (a) *Bull. soc. chim.*, [4], 49, 19-23 (1931); (b) [4], 49, 371-5 (1931); (c) [4], 49, 375-7 (1931); (d) [4], 49, 377-9 (1931); (e) [4], 51, 619-22 (1932); (f) Ivanoff, Mihova, and Christova, *ibid.*, [4], 51, 1321-5 (1932); (g) Ivanoff and Nicoloff, *ibid.*, [4], 51, 1325-31, 1331-7 (1932); (b) Ivanoff and Pchénitchny, *ibid.*, [5], 1, 223-33, 233-5 (1934).

The rates of both the enolization reaction and the "normal" reaction vary with the Grignard reagent employed. Ivanoff and Spassoff (*loc. cit.*^{38e}) have measured the rates of gas evolution in the reactions of several aliphatic organomagnesium halides with chloromagnesium phenylacetate and have found them to increase in the order: CH_3MgI , $i\text{-C}_4\text{H}_9\text{MgBr}$, $s\text{-C}_4\text{H}_9\text{MgBr}$, $n\text{-C}_3\text{H}_7\text{MgBr}$, $\text{C}_2\text{H}_5\text{MgBr}$, $i\text{-C}_3\text{H}_7\text{MgBr}$.

It has also been shown by Ivanoff and Pchénitchny (*loc. cit.*^{38h}) that 3-hexenoïc and styrylacetic acids undergo reactions similar to those of the phenylacetic acids.

According to the observations of McKenzie *et al.*,³⁹ the α -halo phenylacetic acids react in part like alkyl halides, undergoing coupling to a considerable degree. For example,



Quite possibly "reductive enolization" (*q.v.*, Chapter VI) is involved in such reactions.

³⁹ McKenzie, Drew, and Martin, *J. Chem. Soc.*, 107, 26-32 (1915).

TABLE XIII-II
REACTIONS OF GRIGNARD REAGENTS WITH CARBOXYLIC ACIDS AND THEIR SALTS

<u>Acid (or Salt)</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CHO₂			
HCO ₂ H (10.9 g.)	C ₆ H ₅ CH ₂ MgCl (60 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CHO (5.3 g.)	1,2
C₂O₄			
(—CO ₂ H) ₂ (15 g.)	C ₆ H ₅ MgBr (105 g. C ₆ H ₅ Br)	C ₆ H ₅ COCO ₂ H (trace)	21
C₂HO₂Cl₂			
Cl ₂ CHCO ₂ H (10.0 g.)	C ₆ H ₅ MgBr (73.0 g. C ₆ H ₅ Br)	C ₆ H ₅ CH(OH)C(C ₆ H ₅) ₂ OH (8.6 g.)	22
C₂H₃O₂			
CH ₃ CO ₂ H	CH ₃ MgX (3.3 equiv.)	<i>t</i> -C ₄ H ₉ OH (4%)	3
CH ₃ CO ₂ K	CH ₃ MgI	<i>t</i> -C ₄ H ₉ OH	4
CH ₃ CO ₂ H	C ₂ H ₅ MgX (3.3 equiv.)	CH ₃ (C ₂ H ₅) ₂ COH (32%)	3
CH ₃ CO ₂ K	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅) ₂ COH	4
CH ₃ CO ₂ NH ₄	C ₂ H ₅ MgBr	CH ₃ (C ₂ H ₅) ₂ COH	4
CH ₃ CO ₂ Na (42 g.)	<i>i</i> -C ₄ H ₉ MgBr (69 g. C ₄ H ₉ Br)	CH ₃ CO- <i>i</i> -C ₄ H ₉ (25 g., crude)	6
CH ₃ CO ₂ Na	<i>t</i> -C ₄ H ₉ MgCl	(CH ₃) ₂ CO; CH ₃ CO- <i>t</i> -C ₄ H ₉	5
CH ₃ CO ₂ H	<i>n</i> -C ₅ H ₁₁ MgX (3.3 equiv.)	CH ₃ (<i>n</i> -C ₅ H ₁₁) ₂ COH (40–60%)*; CH ₃ CO- <i>n</i> -C ₅ H ₁₁ (10–20%)*	3
CH ₃ CO ₂ Na (42 g.)	<i>i</i> -C ₅ H ₁₁ MgI (99 g. C ₅ H ₁₁ I)	CH ₃ CO- <i>i</i> -C ₅ H ₁₁ (29 g., crude)	6
CH ₃ CO ₂ K	C ₆ H ₅ MgBr	CH ₃ (C ₆ H ₅) ₂ COH	4
CH ₃ CO ₂ Na (42 g.)	C ₆ H ₅ MgBr (79 g. C ₆ H ₅ Br)	CH ₃ COC ₆ H ₅ (30 g., crude)	6
C₃H₅O₂			
C ₂ H ₅ CO ₂ Na (48 g.)	C ₂ H ₅ MgBr (55 g. C ₂ H ₅ Br)	(C ₂ H ₅) ₂ CO (21 g., crude)	6

* These are the ranges of yields reported for a series of reactions.

TABLE XIII-II (Continued)

Acid (or Salt)	RMgX	Product(s)	Ref.
C₃H₅O₂ (<i>cont.</i>)			
C ₂ H ₅ CO ₂ H	<i>n</i> -C ₅ H ₁₁ MgX (3.3 equiv.)	C ₂ H ₅ (<i>n</i> -C ₅ H ₁₁) ₂ COH (40-60%);* C ₂ H ₅ CO- <i>n</i> -C ₅ H ₁₁ (10-20%)*	3
C₄H₄O₃Cl₃			
DL-Cl ₃ CCH(OH)CH ₂ CO ₂ H [†] (20 g.)	C ₆ H ₅ MgBr (75 g. C ₆ H ₅ Br)	DL-Cl ₃ CCH(OH)CH ₂ C(C ₆ H ₅) ₂ OH (6 g.)	22
C₄H₇O₂			
<i>n</i> -C ₃ H ₇ CO ₂ H	CH ₃ MgX (3.3 equiv.)	<i>n</i> -C ₃ H ₇ (CH ₃) ₂ COH (40-60%);* CH ₃ CO- <i>n</i> -C ₃ H ₇ (10-20%)*	3
<i>n</i> -C ₃ H ₇ CO ₂ H	C ₂ H ₅ MgX	<i>n</i> -C ₃ H ₇ (C ₂ H ₅) ₂ COH (40-60%);* C ₂ H ₅ CO- <i>n</i> -C ₃ H ₇ (10-20%)*	3
<i>n</i> -C ₃ H ₇ CO ₂ Na	C ₂ H ₅ MgBr	C ₂ H ₅ CO- <i>n</i> -C ₃ H ₇ ($\bar{\approx}$ 25%)	5
<i>n</i> -C ₃ H ₇ CO ₂ Na	<i>i</i> -C ₃ H ₇ MgBr	(<i>n</i> -C ₃ H ₇) ₂ CO	5
<i>n</i> -C ₃ H ₇ CO ₂ Na	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₃ H ₇ CO- <i>n</i> -C ₄ H ₉ ($\bar{\approx}$ 25%)	5
<i>n</i> -C ₃ H ₇ CO ₂ H	<i>s</i> -C ₄ H ₉ MgBr (3.3 equiv.)	<i>n</i> -C ₃ H ₇ CO- <i>s</i> -C ₄ H ₉ (<15%); <i>n</i> -C ₃ H ₇ (<i>s</i> -C ₄ H ₉) ₂ COH (<1%)	3
<i>n</i> -C ₃ H ₇ CO ₂ Na	<i>t</i> -C ₄ H ₉ MgCl	(<i>n</i> -C ₃ H ₇) ₂ CO	5
<i>n</i> -C ₃ H ₇ CO ₂ H	<i>t</i> -C ₄ H ₉ MgBr (3.3 equiv.)	<i>n</i> -C ₃ H ₇ CO- <i>t</i> -C ₄ H ₉ (<2%); <i>n</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉) ₂ COH (<1%)	3
<i>n</i> -C ₃ H ₇ CO ₂ H	<i>n</i> -C ₅ H ₁₁ MgX (3.3 equiv.)	<i>n</i> -C ₃ H ₇ (<i>n</i> -C ₅ H ₁₁) ₂ COH (40-60%);* <i>n</i> -C ₃ H ₇ CO- <i>n</i> -C ₅ H ₁₁ (10-20%)*	3
<i>n</i> -C ₃ H ₇ CO ₂ Na	C ₆ H ₅ MgBr	<i>n</i> -C ₃ H ₇ COC ₆ H ₅ ($\bar{\approx}$ 25%)	5
<i>i</i> -C ₃ H ₇ CO ₂ H	CH ₃ MgBr	<i>i</i> -C ₃ H ₇ (CH ₃) ₂ COH	9
<i>i</i> -C ₃ H ₇ CO ₂ H	C ₂ H ₅ MgX (3.3 equiv.)	<i>i</i> -C ₃ H ₇ (C ₂ H ₅) ₂ COH (53%); C ₂ H ₅ CO- <i>i</i> -C ₃ H ₇	3
<i>i</i> -C ₃ H ₇ CO ₂ H	C ₂ H ₅ MgX (3.3 equiv.)	<i>i</i> -C ₃ H ₇ (C ₂ H ₅) ₂ COH (70%); C ₂ H ₅ CO- <i>i</i> -C ₃ H ₇	3

* These are the ranges of yields reported for a series of reactions.

[†] When the *levo* acid was so treated, no crystalline product was isolated.

TABLE XIII-II (Continued)

<u>Acid (or Salt)</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₇O₂ (cont.)			
<i>i</i> -C ₃ H ₇ CO ₂ H	<i>n</i> -C ₅ H ₁₁ MgX (3.3 equiv.)	<i>i</i> -C ₃ H ₇ (<i>n</i> -C ₅ H ₁₁) ₂ COH (40–60%);* <i>i</i> -C ₃ H ₇ CO- <i>n</i> -C ₅ H ₁₁ (10–20%)*	3
C₅H₄O₃			
2-Furoic acid (12 g.)	<i>n</i> -C ₃ H ₇ MgI (9 g. Mg)	2- <i>n</i> -Butyrylfuran; 1,1-di- α -furyl-1-butanol	19
2-Furoic acid (12 g.)	<i>i</i> -C ₄ H ₉ MgI (90 g. C ₄ H ₉ I)	2-Isovaleryl-furan, 1,1-di- α -furyl-3-methyl-1-butanol; <i>i</i> -C ₄ H ₉ CH=CHCH ₂ COCO- <i>i</i> -C ₄ H ₉	19
2-Furoic acid	<i>i</i> -C ₅ H ₁₁ MgI	2-Isocaprolylfuran, 1,1-di- α -furyl-4-methyl-1-pentanol; <i>i</i> -C ₅ H ₁₁ CH=CHCH ₂ COCO- <i>i</i> -C ₅ H ₁₁	19
C₅H₉O₂			
<i>n</i> -C ₄ H ₉ CO ₂ H	CH ₃ MgX (3.3 equiv.)	<i>n</i> -C ₄ H ₉ (CH ₃) ₂ COH (40–60%);* CH ₃ CO- <i>n</i> -C ₄ H ₉ (10–20%)*	3
<i>n</i> -C ₄ H ₉ CO ₂ H	C ₂ H ₅ MgX (3.3 equiv.)	<i>n</i> -C ₄ H ₉ (C ₂ H ₅) ₂ COH (40–60%);* C ₂ H ₅ CO- <i>n</i> -C ₄ H ₉ (10–20%)*	3
<i>n</i> -C ₄ H ₉ CO ₂ H	<i>n</i> -C ₄ H ₉ MgX (3.3 equiv.)	(<i>n</i> -C ₄ H ₉) ₃ COH (40–60%);* (<i>n</i> -C ₄ H ₉) ₂ CO (10–20%)*	3
<i>n</i> -C ₄ H ₉ CO ₂ H	<i>n</i> -C ₅ H ₁₁ MgX (3.3 equiv.)	<i>n</i> -C ₄ H ₉ (<i>n</i> -C ₅ H ₁₁) ₂ COH (40–60%);* <i>n</i> -C ₄ H ₉ CO- <i>n</i> -C ₅ H ₁₁ (10–20%)*	3
<i>i</i> -C ₄ H ₉ CO ₂ Na	C ₂ H ₅ MgBr	C ₂ H ₅ CO- <i>i</i> -C ₄ H ₉ ($\bar{\approx}$ 25%)	5
<i>i</i> -C ₄ H ₉ CO ₂ H	C ₂ H ₅ MgX (3.3 equiv.)	<i>i</i> -C ₄ H ₉ (C ₂ H ₅) ₂ COH (40–60%);* C ₂ H ₅ CO- <i>i</i> -C ₄ H ₉ (10–20%)*	3
<i>i</i> -C ₄ H ₉ CO ₂ H	<i>n</i> -C ₅ H ₁₁ MgX (3.3 equiv.)	<i>i</i> -C ₄ H ₉ (<i>n</i> -C ₅ H ₁₁) ₂ COH (40–60%);* <i>i</i> -C ₄ H ₉ CO- <i>n</i> -C ₅ H ₁₁ (10–20%)*	3
<i>i</i> -C ₄ H ₉ CO ₂ MgBr	<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₄ H ₉ (<i>i</i> -C ₅ H ₁₁) ₂ COH	7

* These are the ranges of yields reported for a series of reactions.

TABLE XIII-II (Continued)

<u>Acid (or Salt)</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₉O₂			
C ₂ H ₅ CH=CHCH ₂ CO ₂ H (9 g.)	C ₆ H ₅ MgBr (37.2 g. C ₆ H ₅)	C ₆ H ₅ (C ₂ H ₅ CH=CHCH ₂)C(OH)CH(CH=CHC ₂ H ₅)CO ₂ H (4.5 g. crude)	8
C ₂ H ₅ CH=CHCH ₂ CO ₂ H (11.4 g.)	4-CH ₃ C ₆ H ₄ MgBr (51.3 g. C ₇ H ₇ Br)	4-CH ₃ C ₆ H ₄ (C ₂ H ₅ CH=CHCH ₂)C(OH)CH(CH=CHC ₂ H ₅)CO ₂ H (5.5 g., crude)	8
C₆H₁₁O₂			
<i>n</i> -C ₅ H ₁₁ CO ₂ H	C ₂ H ₅ MgX (3.3 equiv.)	<i>n</i> -C ₅ H ₁₁ (C ₂ H ₅) ₂ COH (40-60%);* C ₂ H ₅ CO- <i>n</i> -C ₅ H ₁₁ (10-20%)*	3
<i>n</i> -C ₅ H ₁₁ CO ₂ H	<i>n</i> -C ₅ H ₁₁ MgX (3.3 equiv.)	(<i>n</i> -C ₅ H ₁₁) ₃ COH (40-60%);* (<i>n</i> -C ₅ H ₁₁) ₂ CO (10-20%)*	3
<i>i</i> -C ₅ H ₁₁ CO ₂ MgBr (from 1 mole <i>i</i> -C ₅ H ₁₁ MgBr)	C ₂ H ₅ MgBr (1.5 equiv.)	<i>i</i> -C ₅ H ₁₁ (C ₂ H ₅) ₂ COH (40-45 g.)	7
C₇H₅O₂			
C ₆ H ₅ CO ₂ Na	CH ₃ MgBr	C ₆ H ₅ (CH ₃) ₂ COH	4
C ₆ H ₅ CO ₂ H	CH ₃ MgI	C ₆ H ₅ (CH ₃) ₂ COH	9
C ₆ H ₅ CO ₂ MgBr	C ₂ H ₅ MgBr	C ₆ H ₅ (C ₂ H ₅) ₂ COH	7
C ₆ H ₅ CO ₂ H	C ₂ H ₅ MgBr	C ₆ H ₅ (C ₂ H ₅) ₂ COH	9
C ₆ H ₅ CO ₂ Na	C ₂ H ₅ MgI	C ₆ H ₅ (C ₂ H ₅) ₂ COH	4
(C ₆ H ₅ CO ₂) ₂ Mg	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ CO (35%)	10
C₈H₂O₄Br₂			
4,5-Br ₂ C ₆ H ₂ -1,2-(CO ₂ H) ₂	C ₂ H ₅ MgBr (<i>ca.</i> 8 equiv.)	3,3-Diethyl-5,6-dibromophthalide; 2-C ₂ H ₅ CO-4,5-Br ₂ C ₆ H ₂ CO ₂ H	11

* These are the ranges of yields reported for a series of reactions.

TABLE XIII-II (Continued)

<u>Acid (or Salt)</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₄O₄			
C ₆ H ₄ -1,2-(CO ₂ H) ₂ (5 g.)	C ₂ H ₅ MgBr (30 g., 8 equiv., C ₂ H ₅ Br)	3,3-Diethylphthalide (1.5 g.); 2-C ₂ H ₅ COC ₆ H ₄ CO ₂ H (1 g.)	11
C ₆ H ₄ -1,2-(CO ₂ H) ₂	<i>n</i> -C ₃ H ₇ MgBr (<i>ca.</i> 8 equiv.)	3,3-Di- <i>n</i> -propylphthalide; 2- <i>n</i> -C ₃ H ₇ COC ₆ H ₄ CO ₂ H	11
C₈H₆O₂Br			
3-BrC ₆ H ₄ CH ₂ CO ₂ MgCl (0.05 mole acid)	C ₆ H ₅ MgBr (0.15 mole C ₆ H ₅ Br)	C ₆ H ₅ (3-BrC ₆ H ₅ CH ₂)C(OH)CH(C ₆ H ₄ -3-Br)CO ₂ H (4.4 g., crude)	12
3-BrC ₆ H ₄ CH ₂ CO ₂ MgCl (9.5 g. acid)	3-CH ₃ C ₆ H ₄ MgBr (22.5 g. C ₇ H ₇ Br)	3-CH ₃ C ₆ H ₄ (3-BrC ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -3-Br)CO ₂ H (4.5 g., crude)	12
3-BrC ₆ H ₄ CH ₂ CO ₂ MgCl (4.6 g. acid)	4-CH ₃ C ₆ H ₄ MgBr (5.1 g. C ₇ H ₇ Br)	4-CH ₃ C ₆ H ₄ (3-BrC ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -3-Br)CO ₂ H	12
DL-C ₆ H ₅ CHBrCO ₂ H (12.5 g.)	C ₆ H ₅ MgBr (37 g., 4 equiv., C ₆ H ₅ Br)	C ₆ H ₅ CH(OH)C(C ₆ H ₅) ₂ OH; (C ₆ H ₅) ₂ CHCO ₂ H; β-[C ₆ H ₅ CH(CO ₂ H)—] ₂ (1.9 g.); α-[C ₆ H ₅ CH(CO ₂ H)—] ₂ (1.8 g.)	13
C₈H₆O₂Cl			
3-ClC ₆ H ₄ CH ₂ CO ₂ MgCl (0.1 mole 3-ClC ₆ H ₄ CH ₂ Cl)	C ₆ H ₅ MgBr (0.15 mole C ₆ H ₅ Br)	C ₆ H ₅ (3-ClC ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -3-Cl)CO ₂ H	12
4-ClC ₆ H ₄ CH ₂ CO ₂ MgCl	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ (4-ClC ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -4-Cl)CO ₂ H ("good yield")	14
4-ClC ₆ H ₄ CH ₂ CO ₂ MgCl (0.1 mole 4-ClC ₆ H ₄ CH ₂ Cl)	C ₆ H ₅ MgBr (0.2 mole)	C ₆ H ₅ (4-ClC ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -4-Cl)CO ₂ H (10 g., 49.8%); 4-ClC ₆ H ₄ CH ₂ (C ₆ H ₅) ₂ COH (?) (8.5 g.)	14
4-ClC ₆ H ₄ CH ₂ CO ₂ MgCl	3-CH ₃ C ₆ H ₄ MgCl	3-CH ₃ C ₆ H ₄ (4-ClC ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -4-Cl)CO ₂ H (13.4 g., 64.5%)	14
4-ClC ₆ H ₄ CH ₂ CO ₂ MgCl	4-CH ₃ C ₆ H ₄ MgCl	4-CH ₃ C ₆ H ₄ (4-ClC ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -4-Cl)CO ₂ H (13.2 g., 63.5%)	14

TABLE XIII-II (Continued)

<u>Acid (or Salt)</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₆O₂Cl (<i>cont.</i>)			
DL-C ₆ H ₅ CHClCO ₂ H	CH ₃ MgI (4 equiv.)	β -[C ₆ H ₅ CH(CO ₂ H)—] ₂ ; α -[C ₆ H ₅ CH(CO ₂ H)—] ₂ ; C ₆ H ₅ CH(OH)CO ₂ H; recovered acid	13
DL-C ₆ H ₅ CHClCO ₂ H	C ₆ H ₅ MgBr	C ₆ H ₅ CH(OH)C(C ₆ H ₅) ₂ OH (10–20%); β -[C ₆ H ₅ CH(CO ₂ H)—] ₂ (5–13%); α -[C ₆ H ₅ CH(CO ₂ H)—] ₂ (0–1%); (C ₆ H ₅) ₂ CHCO ₂ H (1–8%)	13
(–)-C ₆ H ₅ CHClCO ₂ H (30 g.)	C ₆ H ₅ MgBr (111 g., 4 equiv., C ₆ H ₅ Br)	(+)-C ₆ H ₅ CH(OH)C(C ₆ H ₅) ₂ OH (2.2 g., crude; 1.6 g., pure); (C ₆ H ₅) ₂ CHCO ₂ H (3.1 g.); β -[C ₆ H ₅ CH(CO ₂ H)—] ₂ (1 g.); (+)-[C ₆ H ₅ CH(CO ₂ H)—] ₂ (0.2 g.)	13
C₈H₇O₂			
C ₆ H ₅ CH ₂ CO ₂ MgCl	C ₂ H ₅ MgBr (1.5 equiv.)	C ₆ H ₅ CH(MgBr)CO ₂ MgCl; C ₂ H ₆	7
C ₆ H ₅ CH ₂ CO ₂ MgCl (0.1 mole)	C ₆ H ₅ MgBr (0.15 mole)	C ₆ H ₅ (C ₆ H ₅ CH ₂)C(OH)CH(C ₆ H ₅)CO ₂ H (20.2 g., 61%)	14
C ₆ H ₅ CH ₂ CO ₂ MgCl (0.1 mole)	3-CH ₃ C ₆ H ₄ MgBr (0.15 mole)	3-CH ₃ C ₆ H ₄ (C ₆ H ₅ CH ₂)C(OH)CH(C ₆ H ₅)CO ₂ H ("good yield")	14
C ₆ H ₅ CH ₂ CO ₂ MgCl (0.1 mole)	4-CH ₃ C ₆ H ₄ MgBr (0.15 mole)	4-CH ₃ C ₆ H ₄ (C ₆ H ₅ CH ₂)C(OH)CH(C ₆ H ₅)CO ₂ H (62.5%)	14
C₈H₇O₃			
DL-C ₆ H ₅ CH(OH)CO ₂ [–] H ₂ N(CH ₂) ₅ ⁺	C ₆ H ₅ MgX * (3–8 equiv.)	DL-C ₆ H ₅ CH(OH)COC ₆ H ₅ ; DL-C ₆ H ₅ CH(OH)C(C ₆ H ₅) ₂ OH; recovered acid; (C ₆ H ₅ —) ₂	23
C₈H₆O₂N			
C ₆ H ₅ CH(NH ₂)CO ₂ H	C ₆ H ₅ MgBr (4 equiv.)	Recovered acid	15

* X = Br, I.

TABLE XIII-II (Continued)

<u>Acid (or Salt)</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₈O₂			
C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CHCO ₂ H (0.3 mole)	<i>t</i> -C ₅ H ₁₁ MgCl (1.0 mole)	Recovered acid (99%)	20
C₉H₉O₂			
2-CH ₃ C ₆ H ₄ CH ₂ CO ₂ MgCl (10 g. acid)	C ₆ H ₅ MgBr (28 g. C ₆ H ₅ Br)	C ₆ H ₅ (2-CH ₃ C ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -2-CH ₃)CO ₂ H (9.1 g., crude)	12
2-CH ₃ C ₆ H ₄ CH ₂ CO ₂ MgCl (10 g. acid)	3-CH ₃ C ₆ H ₄ MgBr (28 g. C ₇ H ₇ Br)	3-CH ₃ C ₆ H ₄ (2-CH ₃ C ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -2-CH ₃)CO ₂ H (8 g., crude)	12
2-CH ₃ C ₆ H ₄ CH ₂ CO ₂ MgCl (10 g. acid)	4-CH ₃ C ₆ H ₄ MgBr (28 g. C ₇ H ₇ Br)	4-CH ₃ C ₆ H ₄ (2-CH ₃ C ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -2-CH ₃)CO ₂ H (8.8 g., crude)	12
3-CH ₃ C ₆ H ₄ CH ₂ CO ₂ MgCl (0.1 mole 3-CH ₃ C ₆ H ₄ CH ₂ Cl)	C ₆ H ₅ MgBr (0.15 mole C ₆ H ₅ Br)	C ₆ H ₅ (3-CH ₃ C ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -3-CH ₃)CO ₂ H (10.2 g., crude)	12
3-CH ₃ C ₆ H ₄ CH ₂ CO ₂ MgCl (0.1 mole 3-CH ₃ C ₆ H ₄ CH ₂ Cl)	3-CH ₃ C ₆ H ₄ MgBr (0.15 mole C ₇ H ₇ Br)	3-CH ₃ C ₆ H ₄ (3-CH ₃ C ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -3-CH ₃)CO ₂ H (9.8 g., crude)	12
3-CH ₃ C ₆ H ₄ CH ₂ CO ₂ MgCl (0.1 mole 3-CH ₃ C ₆ H ₄ CH ₂ Cl)	4-CH ₃ C ₆ H ₄ MgBr (0.15 mole C ₇ H ₇ Br)	4-CH ₃ C ₆ H ₄ (3-CH ₃ C ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -3-CH ₃)CO ₂ H (9.5 g., crude)	12
4-CH ₃ C ₆ H ₄ CH ₂ CO ₂ MgCl (0.1 mole 4-CH ₃ C ₆ H ₄ CH ₂ Cl)	C ₆ H ₅ MgBr	C ₆ H ₅ (4-CH ₃ C ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -4-CH ₃)CO ₂ H (7.3 g., crude)	12
4-CH ₃ C ₆ H ₄ CH ₂ CO ₂ MgCl (0.1 mole 4-CH ₃ C ₆ H ₄ CH ₂ Cl)	3-CH ₃ C ₆ H ₄ MgBr (0.15 mole C ₇ H ₇ Br)	3-CH ₃ C ₆ H ₄ (4-CH ₃ C ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -4-CH ₃)CO ₂ H (5.8 g., crude)	12
4-CH ₃ C ₆ H ₄ CH ₂ CO ₂ MgCl (0.1 mole 4-CH ₃ C ₆ H ₄ CH ₂ Cl)	4-CH ₃ C ₆ H ₄ MgBr (0.15 mole C ₇ H ₇ Br)	4-CH ₃ C ₆ H ₄ (4-CH ₃ C ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -4-CH ₃)CO ₂ H (5.8 g., crude)	12
C₉H₁₀O₂N			
DL-C ₆ H ₅ CH ₂ CH(NH ₂)CO ₂ H (3 g.)	C ₆ H ₅ MgBr (34 g., 12 equiv., C ₆ H ₅ Br)	DL-C ₆ H ₅ CH ₂ CH(NH ₂)C(C ₆ H ₅) ₂ OH (4 g., crude; 2.4 g., pure)	16
(+)-C ₆ H ₅ CH ₂ CH(NH ₂)CO ₂ H (3 g.)	C ₆ H ₅ MgBr (34 g., 12 equiv., C ₆ H ₅ Br)	(+)-C ₆ H ₅ CH ₂ CH(NH ₂)C(C ₆ H ₅) ₂ OH (4.2 g., crude)	16

TABLE XIII-II (Continued)

<u>Acid (or Salt)</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₀O₂N (<i>cont.</i>)			
CH ₃ (C ₆ H ₅)C(NH ₂)CO ₂ H (6 g.)	C ₆ H ₅ MgBr (71 g., 12 equiv., C ₆ H ₅ Br)	CH ₃ (C ₆ H ₅)C(NH ₂)C(C ₆ H ₅) ₂ OH (5 g., crude; 2 g., pure)	16
C₁₀H₈O₆			
3,4-(CH ₃ O) ₂ C ₆ H ₂ -1,2-(CO ₂ H) ₂ (6.9 g.)	C ₂ H ₅ MgBr (<i>ca.</i> 8 equiv.)	3,3-Diethyl-4,5-dimethoxyphthalide; 3,3-diethyl-6,7-dimethoxyphthalide; 2-C ₂ H ₅ CO-3,4-(CH ₃ O) ₂ C ₆ H ₂ CO ₂ H; 2,3-(CH ₃ O) ₂ -6-C ₂ H ₅ COC ₆ H ₂ CO ₂ H	11
C₁₀H₉O₂			
C ₆ H ₅ CH=CHCH ₂ CO ₂ H (5 g.)	C ₆ H ₅ MgBr (12 g. C ₆ H ₅ Br)	C ₆ H ₅ (C ₆ H ₅ CH=CHCH ₂)C(OH)CH(CH=CHC ₆ H ₅)CO ₂ H (4.9 g., crude)	8
C ₆ H ₅ CH=CHCH ₂ CO ₂ H (5 g.)	3-CH ₃ C ₆ H ₄ MgBr (13.2 g. C ₇ H ₇ Br)	3-CH ₃ C ₆ H ₄ (C ₆ H ₅ CH=CHCH ₂)C(OH)CH(CH=CHC ₆ H ₅)CO ₂ H (4.7 g., crude)	8
C ₆ H ₅ CH=CHCH ₂ CO ₂ H (2.5 g.)	4-CH ₃ C ₆ H ₄ MgBr (6.6 g. C ₇ H ₇ Br)	4-CH ₃ C ₆ H ₄ (C ₆ H ₅ CH=CHCH ₂)C(OH)CH(CH=CHC ₆ H ₅)CO ₂ H (2.2 g., crude)	8
C₁₀H₉O₄			
2-H ₅ C ₂ O ₂ CC ₆ H ₄ CO ₂ H	C ₂ H ₅ MgBr	3,3-Diethylphthalide	17
2-H ₅ C ₂ O ₂ CC ₆ H ₄ CO ₂ H	C ₆ H ₅ MgBr (4 equiv.)	"1,1-Diphenyl-3-phenylenephthalan"	17
2-H ₅ C ₂ O ₂ CC ₆ H ₄ CO ₂ H	C ₆ H ₅ CH ₂ MgCl	3,3-Dibenzylphthalide; 1,1-dibenzyl-3-benzylidenephthalan	17
C₁₁H₁₃O₂			
4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ CO ₂ MgCl (10.5 g. 4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ Cl)	C ₆ H ₅ MgBr (14.5 g. C ₆ H ₅ Br)	C ₆ H ₅ (4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -4- <i>i</i> -C ₃ H ₇)CO ₂ H (10.6 g., crude)	12
4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ CO ₂ MgCl (0.05 mole 4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ Cl)	3-CH ₃ C ₆ H ₄ MgBr (0.075 mole C ₇ H ₇ Br)	3-CH ₃ C ₆ H ₄ (4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -4- <i>i</i> -C ₃ H ₇)CO ₂ H ("good yield")	12

TABLE XIII-II (Continued)

<u>Acid (or Salt)</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₃O₂ (<i>cont.</i>)			
4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ CO ₂ MgCl	4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ (4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂)C(OH)CH(C ₆ H ₄ -4- <i>i</i> -C ₃ H ₇)CO ₂ H	12
C₁₁H₁₄O₂N			
2-(C ₂ H ₅) ₂ NC ₆ H ₄ CO ₂ H (30 g.)	C ₂ H ₅ MgBr (110 g. C ₂ H ₅ Br)	3,3-Diethylphthalide (26 g.)	18
C₁₂H₉O₂			
2-C ₁₀ H ₇ CH ₂ CO ₂ MgCl (9 g. acid)	C ₆ H ₅ MgBr (23 g. C ₆ H ₅ Br)	C ₆ H ₅ (β-C ₁₀ H ₇ CH ₂)C(OH)CH(β-C ₁₀ H ₇)CO ₂ H (8.8 g., crude)	12
C₁₂H₁₄O₃N			
2-(C ₂ H ₅) ₂ NOCC ₆ H ₄ CO ₂ H (30 g.)	C ₂ H ₅ MgBr (110 g. C ₂ H ₅ Br)	3,3-Diethylphthalide (26 g., 80%)	18
C₁₂H₁₇O₂			
β-(1,3,3-Trimethyl-2-cyclohexenyl)acrylic acid	CH ₃ MgBr	(C ₉ H ₁₅)CH=CHC(CH ₃) ₂ OH	9
Sodium β-(1,3,3-trimethyl-2-cyclohexenyl)acrylate	CH ₃ MgBr	(C ₉ H ₁₅)CH=CHC(CH ₃) ₂ OH	4
C₁₂H₂₃O₂			
<i>n</i> -C ₁₁ H ₂₃ CO ₂ Na	C ₂ H ₅ MgBr	C ₂ H ₅ CO- <i>n</i> -C ₁₁ H ₂₃ ($\bar{\bar{c}}$ 25%)	5

REFERENCES FOR TABLE XIII-II

- (1) Houben, *Chem.-Ztg.*, 29, 667 (1905); *J. Chem. Soc.*, 88,1, 600 (1905).
- (2) Zelinsky, *Chem.-Ztg.*, 28, 303 (1904).
- (3) Huston and Bailey, *J. Am. Chem. Soc.*, 68, 1382-3 (1946).
- (4) Friedr. Baeyer & Co., German Patent 166,899, Nov. 13, 1905; *Friedlaender*, 8, 1294-5 (1905-1907).
- (5) Petrov and Sokolova, *J. Gen. Chem. (U.S.S.R.)*, 8, 199-206 (1938); *Chem. Abstr.*, 32, 5376 (1938).
- (6) Salkind and Beburischwili, *Ber.*, 42, 4500-3 (1909).
- (7) Grignard, *Bull. soc. chim.*, [3], 31, 751-7 (1904); *Compt. rend.*, 138, 152-4 (1904); *J. Chem. Soc.*, 86,1, 213 (1904).
- (8) Ivanoff and Pchénitchny, *Bull. soc. chim.*, [5], 1, 233-5 (1934).
- (9) Friedr. Baeyer & Co., German Patent 166,898, Nov. 13, 1905; *Friedlaender*, 8, 1292-3 (1905-1907).
- (10) Ivanoff, *Compt. rend.*, 186, 442-4 (1928); *Chem. Abstr.*, 22, 3159 (1928).
- (11) Simonis and Arand, *Ber.*, 42, 3721-8 (1909).
- (12) Ivanoff and Pchénitchny, *Bull. soc. chim.*, [5], 1, 223-33 (1934).
- (13) McKenzie, Drew, and Martin, *J. Chem. Soc.*, 107, 26-32 (1915).
- (14) Ivanoff and Spasoff, *Bull. soc. chim.*, [4], 49, 371-5 (1931).
- (15) McKenzie and Richardson, *J. Chem. Soc.*, 123, 79-91 (1923).
- (16) McKenzie and Wills, *J. Chem. Soc.*, 127, 283-95 (1925).
- (17) Shibata, *J. Chem. Soc.*, 95, 1449-56 (1909).
- (18) Maxim, *Ann. chim.*, [10], 9, 55-111 (1928).
- (19) Kuznetsov, *J. Gen. Chem. (U.S.S.R.)*, 12, 631-7 (1942). *Chem. Abstr.*, 38, 1494 (1944).
- (20) Whitmore, Whitaker, Mosher, Breivik, Wheeler, Miner, Sutherland, Wagner, Clapper, Lewis, Lux, and Popkin, *J. Am. Chem. Soc.*, 63, 643-54 (1941).
- (21) McKenzie and Duff, *Ber.*, 60B, 1335-41 (1927).
- (22) Boyle, McKenzie, and Mitchell, *Ber.*, 70B, 2153-60 (1937).
- (23) McKenzie, Martin, and Rule, *J. Chem. Soc.*, 105, 1583-91 (1914).

CHAPTER XIV

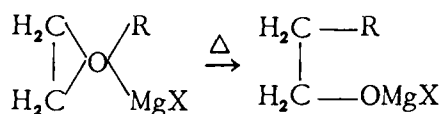
Reactions of Grignard Reagents with Epoxides*

ETHYLENE OXIDE

The reactions of ethylene oxide with alkylmagnesium bromides were first investigated by Blaise,¹ who concluded that the addition of the reagent to the oxide takes place in two ways, forming $\text{RCH}_2\text{CH}_2\text{OMgBr}$ and $\text{BrCH}_2\text{CH}_2\text{OMgR}$, respectively, with the latter predominating.

Whereas this finding appeared to have a bearing on the Grignard-Baeyer controversy concerning the nature and constitution of Grignard reagent-ether oxonium complexes (see Chapter IV), it was naturally reinvestigated by Grignard.² Operating at a temperature of about -15° , Grignard added a precooled ether-ethylene oxide solution to a refrigerated ethereal solution of ethylmagnesium bromide. The system was allowed to warm slowly to room temperature, and then to stand for about twenty-four hours. Finally, ether, together with any excess ethylene oxide, was removed by water-bath distillation. Near the completion of the distillation a vigorous exothermic reaction took place. Upon hydrolytic treatment of the product Grignard was able to isolate *n*-butyl alcohol equivalent to about 83 percent of the ethylene oxide used.

Grignard conceived of the reaction as taking place in two "phases": (1) the formation of an oxonium complex analogous to the ether complex previously postulated, and (2) thermal rearrangement of the complex.



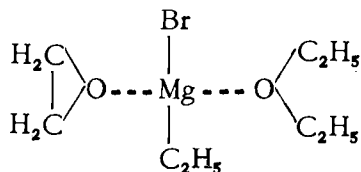
Although at that time unaware of the phenomenon now known as the Schlenk equilibrium (see Chapter IV), Grignard attributed bromohydrin formation to reaction of the epoxide with magnesium bromide (arising from the Wurtz side-reaction in the preparation of the Grignard reagent). He accounted for the observation of Blaise on the assumption that under the conditions employed the Grignard reagent-oxide reaction had been substantially arrested in the "first phase."

*The Grignard and other reactions of epoxides have been reviewed by Winstein and Henderson in Chapter I (pp. 1-60), Volume I of Elderfield's "Heterocyclic Compounds," John Wiley & Sons, Inc., New York, 1950. See also: "The Reaction between Grignard Reagents and the Oxirane Ring," Gaylord and Becker, *Chem. Revs.*, 49, 413-533 (1950).

¹Blaise, *Compt. rend.*, 134, 551-3 (1902); *J. Chem. Soc.*, 82,1, 357 (1902).

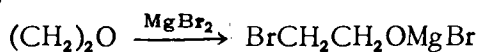
²Grignard, *Bull. soc. chim.*, [3], 29, 944-8 (1903).

Meisenheimer³ formulated Grignard's initial product as a Werner complex:

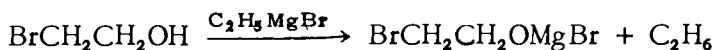


A crystalline precipitate formed at *ca.* -20° , however, gave bromine and magnesium analyses corresponding to $\text{C}_2\text{H}_5\text{MgBr} \cdot \text{C}_2\text{H}_4 \cdot 0.1/4 (\text{C}_2\text{H}_5)_2\text{O}$. His general conclusions were in substantial agreement with those of Grignard.

Ribas and Tapia⁴ have shown that even at -21° magnesium bromide reacts readily with epoxides in ethereal solution as described by Grignard (*loc. cit.*²),



the products being identical with those obtained by treatment of the corresponding bromohydrins with one equivalent of ethylmagnesium bromide.



They interpret Grignard's first reaction stage as consisting in the formation of insoluble and relatively unreactive $\text{BrCH}_2\text{CH}_2\text{OMgBr}$ by interaction of ethylene oxide with magnesium bromide arising from the Schlenk equilibrium. This product is capable of reacting with a second molecule of ethylene oxide to form a product to which they ascribe the formula $(\text{BrCH}_2\text{CH}_2\text{O})_2\text{Mg}$.

Huston and Agett⁵ have found that the initial product of the reaction of ethylmagnesium bromide with ethylene oxide has the empirical formula $\text{C}_4\text{H}_8\text{Br}_2\text{MgO}_2$. However, upon hydrolysis, half the bromine present appears in ionic form. Perhaps, as Cottle and Hollyday⁶ have suggested, this material is actually a complex of one molecule of ethylene oxide-magnesium bromide reaction product with an additional molecule of ethylene oxide: $\text{BrCH}_2\text{CH}_2\text{OMgBr} \cdot \text{O}(\text{CH}_2)_2$. According to Huston and Agett, neither the Grignard reagent itself nor the dialkylmagnesium compound react appreciably with ethylene oxide until all the magnesium bromide present has reacted. They therefore represent the "normal" reaction of an alkylmagnesium bromide with ethylene oxide as follows:

- (1) $2 \text{RMgBr} \rightleftharpoons \text{MgBr}_2 + \text{R}_2\text{Mg}$
- (2) $\text{MgBr}_2 + 2 (\text{CH}_2)_2\text{O} \rightarrow \text{C}_4\text{H}_8\text{Br}_2\text{MgO}_2$
- (3) $\text{C}_4\text{H}_8\text{Br}_2\text{MgO}_2 + \text{R}_2\text{Mg} \rightarrow (\text{RCH}_2\text{CH}_2\text{O})_2\text{Mg} + \text{MgBr}_2$
- (4) $(\text{RCH}_2\text{CH}_2\text{O})_2\text{Mg} + 2 \text{H}_2\text{O} \rightarrow 2 \text{RCH}_2\text{CH}_2\text{OH} + \text{Mg}(\text{OH})_2$

³Meisenheimer, *Ann.*, 442, 180-210 (1925).

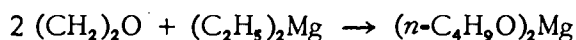
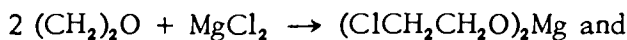
⁴Ribas and Tapia, *Anales. soc. españ. fís. quim.*, 28, 636-44 (1930); 30, 778-91. 944-70 (1932); *Chem. Abstr.*, 24, 4265 (1930); 27, 1323, 1864 (1933).

⁵Huston and Agett, *J. Org. Chem.*, 6, 123-33 (1941).

⁶Cottle and Hollyday, *J. Org. Chem.*, 12, 510-6 (1947).

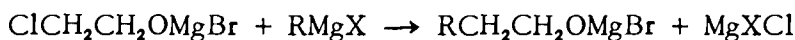
In support of the reaction scheme proposed they cite the additional observations that: (a) $C_4H_8Br_2MgO_2$ from magnesium bromide and ethylene oxide, when suspended in an ethereal solution of ethylmagnesium bromide and heated, gives an excellent yield of *n*-butyl alcohol; (b) $C_4H_8Br_2MgO_2$ from *n*-propylmagnesium bromide and ethylene oxide, when suspended in ethereal di-*n*-amylmagnesium and heated, yields *n*-heptyl alcohol; (c) $C_4H_8Br_2MgO_2$ from *n*-amylmagnesium bromide and ethylene oxide, suspended in di-*n*-propylmagnesium and heated, yields *n*-amyl alcohol; (d) dialkylmagnesium compounds, prepared by the dioxane precipitation method, react at room temperature with two equivalents of ethylene oxide to give good yields of alcohol.

Huston and Langham⁷ have observed that when ethylmagnesium chloride is allowed to react with two molecular equivalents of ethylene oxide in cold ethereal solution, calculation of the yields of *n*-butyl alcohol (*ca.* 80 percent) and ethylene chlorohydrin (*ca.* 70 percent) must be based upon the stoichiometrical equations,



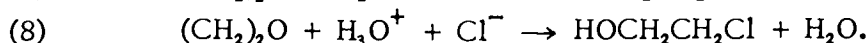
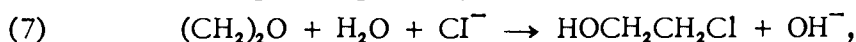
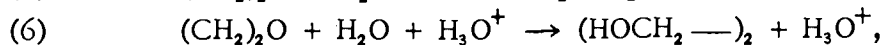
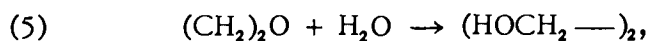
if they are not to aggregate considerably more than 100 percent.

Taken in conjunction with Grignard's⁸ earlier observation that β -chloroethoxymagnesium bromide, upon prolonged reflux in ethereal Grignard reagent solutions, or upon heating with Grignard reagents at higher temperatures, reacts to form alcohols according to the equation



these facts seem to afford a fair qualitative picture of the course of ethylene oxide reactions, although the details of reaction mechanism are still obscure.

However, as in the case of the enolization reactions (see Chapter VI, Enolate Formation by Grignard Reagents), it should be possible to recognize some useful analogies between aqueous and Grignard reactions. Brønsted *et al.*⁹ conclude from the results of kinetic studies that, in the presence of aqueous hydrochloric acid, ethylene oxide disappears by four different paths:



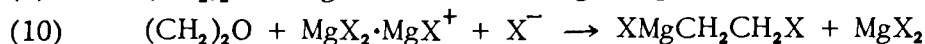
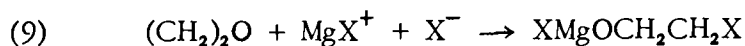
Reaction 6 is much more rapid than reaction 5, and reaction 8 is much more rapid than reaction 7. In other words, the epoxide ring-opening is acid-catalyzed.

⁷Huston and Langham, *J. Org. Chem.*, 12, 90-5 (1947).

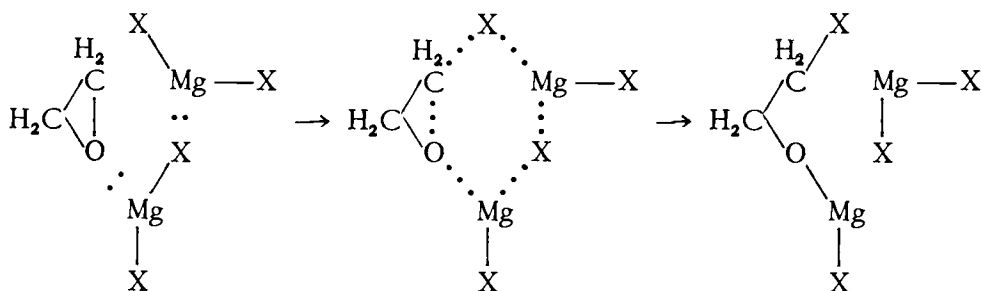
⁸Grignard, *Compt. rend.*, 141, 44-6 (1905); *J. Chem. Soc.*, 88, 1, 593 (1905); *Bull. soc. chim.*, [3], 33, 918-9 (1905); *Ann. chim.*, [8], 10, 23-40 (1905).

⁹Brønsted, Kilpatrick, and Kilpatrick, *J. Am. Chem. Soc.*, 51, 428-61 (1929).

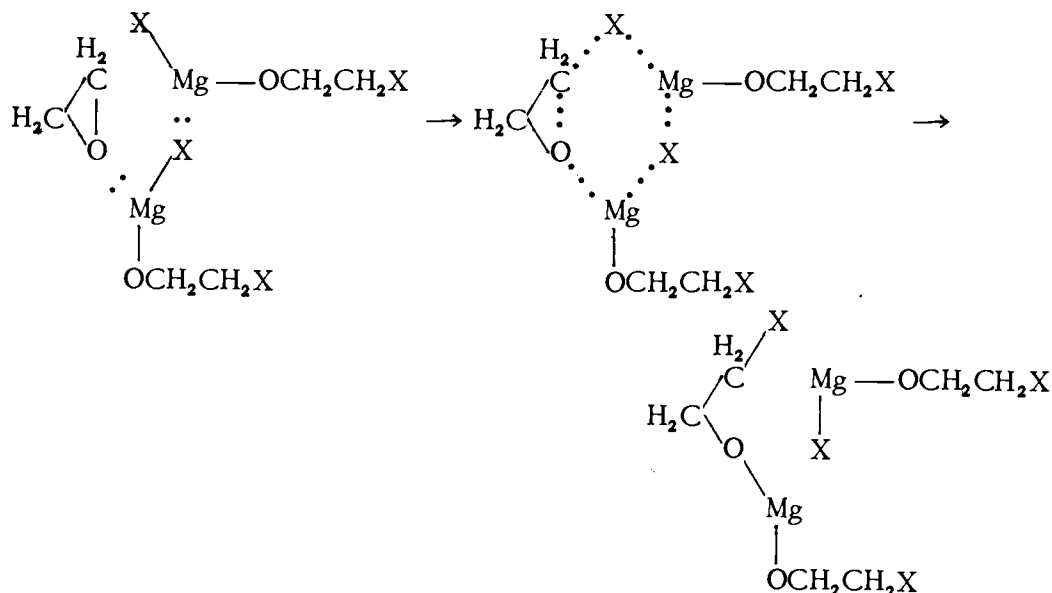
In magnesium halide cleavage of the epoxide ring (with halohydrate formation), among the (Lewis) acids present or potentially available are MgX_2 and MgX^+ . The formal analogy between equations 8 and 9 (or 10) is obvious.



However, because actual ionic dissociation in media of such low dielectric constants as ethereal epoxide solutions must be very slight indeed, there is strong incentive to seek a plausible concerted reaction mechanism which does not necessarily presuppose material ionic dissociation prior to reaction.* A hypothetical quasi six-membered ring transition state analogous to some of those previously proposed for other reactions might be invoked to that end.



A similar reaction scheme involving $\text{XCH}_2\text{CH}_2\text{OMgX}$ or combinations of $\text{XCH}_2\text{CH}_2\text{OMgX}$ and MgX_2 would account for the high yields of halohydrins obtained in magnesium halide epoxide ring cleavages.



Extensions of this concept to the postulation of reaction schemes for the formation of alcohols from ethylene oxide and diorganomagnesium compounds, and for the formation of mixtures of halohydrins and alcohols

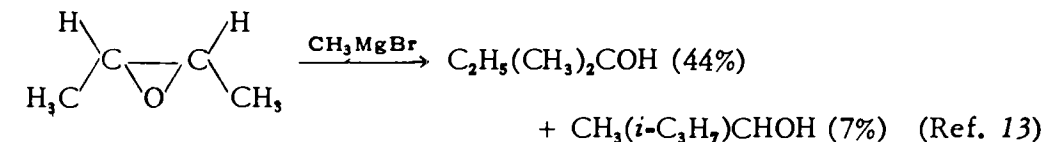
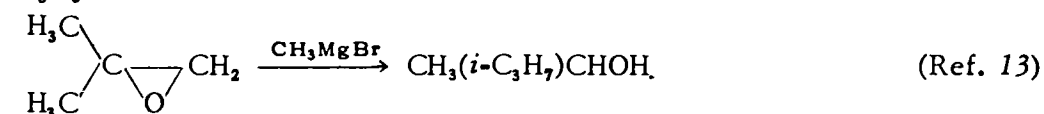
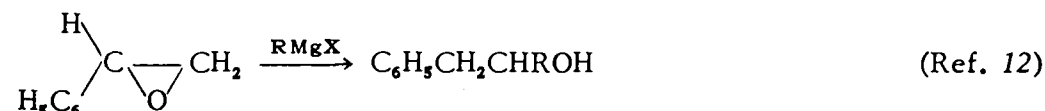
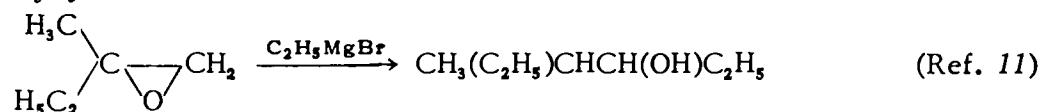
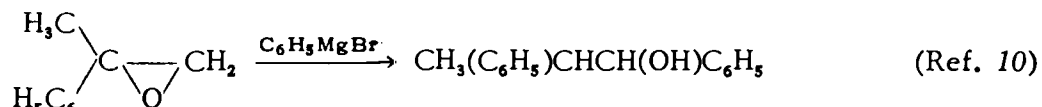
*There are also stereochemical reasons (to be discussed later) for postulating an intermediate of some structural stability.

from ethylene oxide and the mixture of components commonly designated by the convenient but fictional simplification RMgX are obvious. It should again be emphasized, however, that all such representations are over-simplifications designed merely to outline the minimum essentials of more complicated systems.

It may also be pointed out that, whereas the acids which facilitate epoxide ring-opening by coördination with the epoxide oxygen are themselves consumed in the resultant transformations, these processes are not "acid-catalyzed" in the classical sense of the term. Perhaps it might be said with propriety that the epoxide is "acid-activated," or that the reaction is "acid-induced" or "acid-expedited."

EPOXIDE ISOMERIZATION

Reactions yielding alcohols in which both the hydroxyl group and the organic radical of the Grignard reagent are attached to the same carbon atom were early observed by Tiffeneau^{10,11,12}, and by Henry.¹³



Other examples are recorded in Table XIV-I.

The only plausible explanation for these reactions would appear to be that offered by Henry (*loc. cit.*¹³); namely, that the epoxides are isomerized to the corresponding aldehydes (or ketones), and react as such.

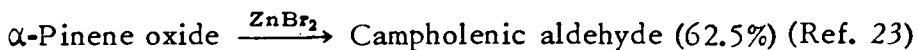
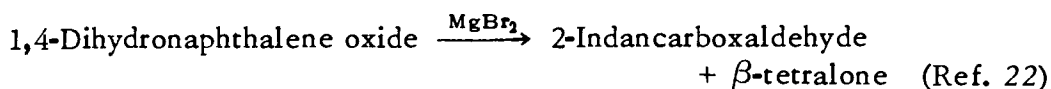
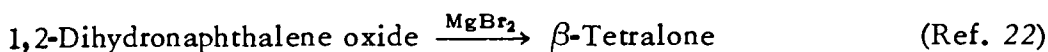
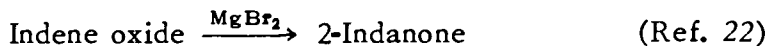
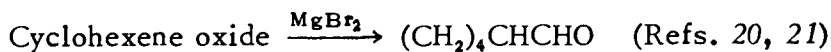
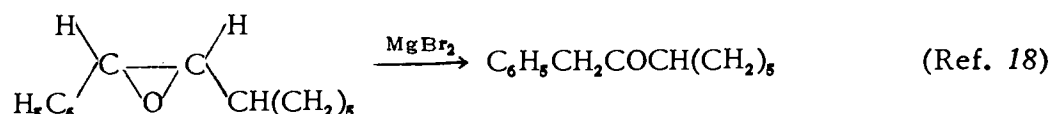
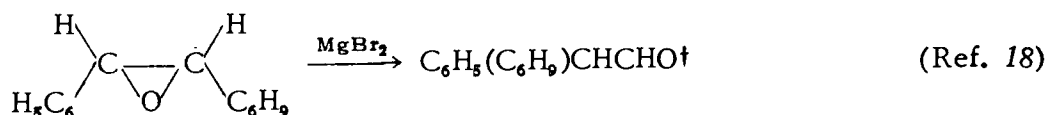
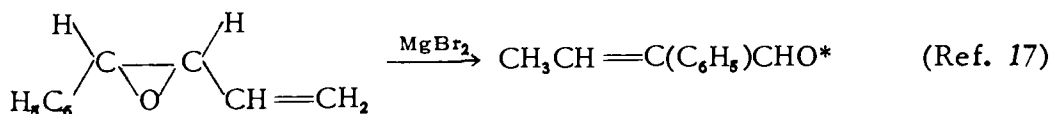
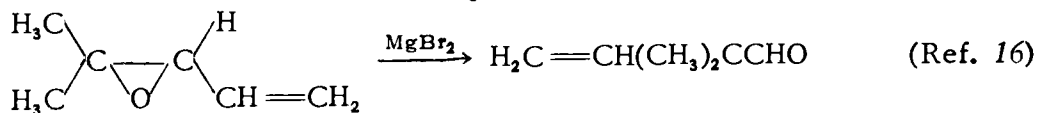
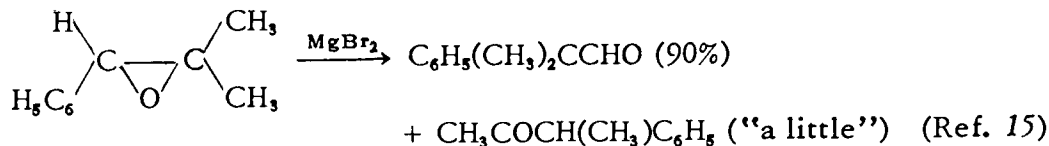
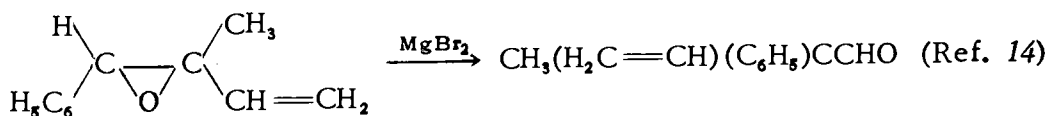
Of the numerous reported instances of the magnesium (or zinc) halide isomerization of epoxides, the following examples may serve as representative.

¹⁰Tiffeneau, *Compt. rend.*, 140, 1458-60 (1905); *Chem. Zentr.*, 1905,II, 235.

¹¹Fourneau and Tiffeneau, *Compt. rend.*, 145, 437-9 (1907); *Chem. Zentr.*, 1907,II, 1320.

¹²Tiffeneau and Fourneau, *Compt. rend.*, 146, 677-9 (1908); *Chem. Zentr.*, 1908,I, 1776.

¹³Henry, *Compt. rend.*, 145, (a) 21-5, (b) 154-6, (c) 406-8 (1907); *Chem. Zentr.*, 1907,II, 1320; *J. Chem. Soc.*, 92,I, 745 (1907).



¹⁴Deux, *Compt. rend.*, 206, 1017-9 (1938); *Chem. Abstr.*, 32, 4965 (1938).

¹⁵Poctivas and Tchoubar, *Compt. rend.*, 205, 287-8 (1937); *Chem. Abstr.*, 31, 7853 (1937).

¹⁶Deux, *Compt. rend.*, 209, 920-1 (1938); *Chem. Abstr.*, 33, 1660 (1939).

*The product reported is "phenylcrotonaldehyde," which implies a double-bond shift as well as a hydrobenzoin-type rearrangement. The isocrotonaldehydes are apparently unstable.

¹⁷Deux, *Compt. rend.*, 211, 441-3 (1940); *Chem. Abstr.*, 36, 1307 (1942).

[†] C_6H_9 = 1-cyclohexenyl.

¹⁸Tiffeneau and Kuriaki, *Compt. rend.*, 209, 465-8 (1939); *Chem. Abstr.*, 34, 731 (1940).

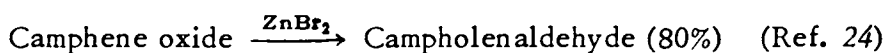
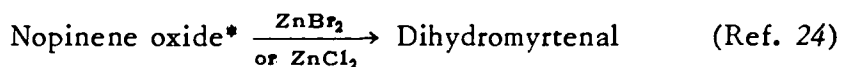
¹⁹Tiffeneau, Weill, and Tchoubar, *Compt. rend.*, 205, 54-6 (1937); *Chem. Abstr.*, 31, 7409 (1937).

²⁰Bedos, *Compt. rend.*, 189, 255-7 (1929); *Chem. Abstr.*, 24, 76 (1930).

²¹Clemo and Ormston, *J. Chem. Soc.*, 1933, 362.

²²Tchoubar, *Compt. rend.*, 214, 117-9 (1942); *Chem. Abstr.*, 37, 3427 (1943).

²³Ritter and Russel, *J. Am. Chem. Soc.*, 58, 291-3 (1936).



All these reactions appear to be truly acid-catalyzed in the Lewis sense, although it may be necessary to supply one equivalent or more of catalyst because of complex formation between product and catalyst.

It is commonly assumed: (a) that the simpler epoxides (e.g., ethylene oxide, α -epichlorohydrin, and propylene oxide) have little or no tendency to rearrange, and (b) that rearrangement of the more complex epoxides is effected solely or principally by the MgX_2 component of the Grignard reagent. From a practical quantitative standpoint these assumptions are not seriously in error. As implying fundamental distinctions of kind rather than of degree, however, they are to be taken *cum grano salis*. In illustration, Cottle and Hollyday (*loc. cit.*⁶), in a preparation involving fairly large quantities of ethylene oxide (11.33 moles) and di-*n*-butylmagnesium (4.20 moles), isolated, in addition to a 43.5 percent yield of 1-hexanol (the "normal" product), an 0.8 percent yield of 2-hexanol, which must have had its origin in isomerization of the oxide to acetaldehyde.

Although the mechanisms of the epoxide reactions are not actually known, it would seem reasonable to suppose that, if the addition reactions (halohydrinate and alcoholate formation) are trimolecular, the isomerization reactions are probably bimolecular. This supposition is consistent with the observation of Kharasch and Clapp²⁵ that the predominant product of the interaction of styrene oxide with phenylmagnesium bromide depends upon the order of reagent addition. When the oxide is added gradually to the Grignard reagent, so that most of the reaction takes place in the presence of an excess of Grignard reagent, the "normal" addition reaction (presumably requiring two molecules of Grignard reagent components per molecule of oxide) yields the predominant product, 2,2-diphenylethanol. When, however, the reverse addition is employed, so that most of the reaction takes place in the presence of an excess of oxide, the major product is the alcohol (1,2-diphenylethanol) arising from the presumably bimolecular isomerization.[†]

FACTORS INFLUENCING DIRECTION OF RING-OPENING

Both the addition reactions (halohydrinate and alcoholate formation) and the isomerization reactions (aldehyde or ketone formation) involve the opening of the oxirane ring. For the unsymmetrical epoxides it be-

* β -Pinene oxide.

²⁴Arbuzov, *J. Gen. Chem.* (U.S.S.R.), 9, 255-71 (1939); *Chem. Abstr.*, 33, 6280 (1939).

²⁵Kharasch and Clapp, *J. Org. Chem.*, 3, 355-60 (1938).

[†]It may be noted that in this particular instance the product in question could conceivably arise from a "normal" addition reaction in which the direction of ring-opening is reversed. It is difficult, however, to conjure up any plausible explanation as to how reversal of the order of reagent addition could reverse the direction of ring-opening.

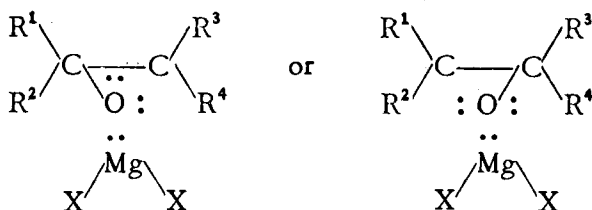
comes a matter of some interest to determine whether or not the direction of ring opening can be accounted for on acceptable theoretical grounds that permit extension to the confident prediction of behavior in cases as yet unknown. Because the two types of reactions are fundamentally dissimilar it is necessary to consider them separately.

Ring-Opening in Isomerizations. For the sake of simplicity, and because of the greater abundance of relevant experimental evidence this discussion is limited to rearrangements of the hydrobenzoïn type.* Upon a purely statistical basis it might be concluded that the tendency is for the rearrangement, whenever possible, to take a course leading to aldehyde formation in preference to ketone formation. At best such a generalization would be empirical, and it encounters at least one glaring exception in the magnesium bromide isomerization of α -phenyl- β -cyclohexylethylene oxide to form cyclohexyl benzyl ketone rather than phenylcyclohexylacetaldehyde (Ref. 18).

Attempts have been made to relate the courses of such rearrangements to the relative migratory aptitudes of the transient groups, or to the converse property—the relative “affinities” of the non-transient groups. It has been estimated that relative migratory aptitudes run in the order: $C_6H_5 > H_2C=CH > H > CH_3 >$ higher alkyl groups. Deux (*loc. cit.*¹⁴) states that the “affinities” of the methyl and vinyl groups are superior to that of the phenyl group, and thus seeks to account for the magnesium bromide isomerization of 3-methyl-3,4-epoxy-4-phenyl-1-butene to form 2-methyl-2-phenyl-3-butenal rather than 4-phenyl-1-penten-3-one or 3-phenyl-4-penten-2-one.

The present authors believe, however, that the most promising approach to a solution of this problem is by way of a variation of the Whitmore mechanism²⁶ for the pinacol, hydrobenzoïn, and related intramolecular rearrangements.²⁷ Although it seems probable that the processes involved in such rearrangements may be simultaneous rather than successive, it is convenient for expository purposes to divide them into stages.

The first, and primarily directive, stage in the (Lewis) acid-catalyzed rearrangement of an epoxide may be conceived of as the scission of one of the carbon-oxygen bonds of the oxirane ring.

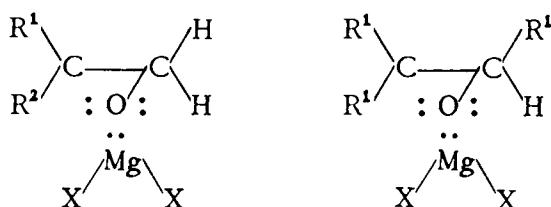


*See: Porter, “Molecular Rearrangements,” A.C.S. Monograph Series, The Chemical Catalog Co., Inc., New York, 1928, pp. 106ff.

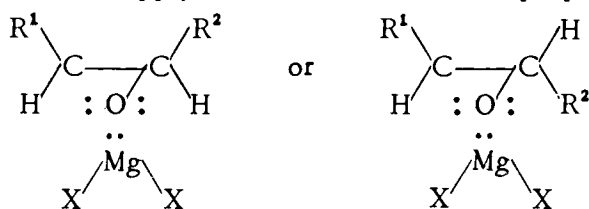
²⁶Whitmore, *J. Am. Chem. Soc.*, 54, 3274–83 (1932).

²⁷For an excellent and well-documented discussion of the mechanisms of such rearrangements see: Wheland, “Advanced Organic Chemistry,” John Wiley & Sons, Inc., New York, 2nd ed., 1949, pp. 475ff.

At this stage the *alpha* carbon atom (that from which the oxygen atom is detached) would remain with an "open sextet" of valence electrons. According to the Kharasch "electronegativity" theory,²⁸ the relatively electron-deficient carbon atom of the oxirane ring should become the *alpha* carbon atom. When as many as two of the R groups are hydrogen atoms and the other two are *gem* hydrocarbon radicals, or when one R group is a hydrogen atom and the other three are identical hydrocarbon radicals, no difficulty need be experienced in predicting the direction of ring-opening.



In the case of the unsymmetrically α,β -disubstituted oxirane, that carbon atom which bears the more "electronegative" substituent will become the *alpha* carbon atom; *i.e.*, if R^1 is more "electronegative" than R^2 , the following diagrams will apply to the formation of the preponderant product.



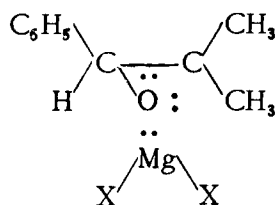
When R^1 and R^2 differ but little in "electronegativity" the product ratio may approach 50 : 50, but as the disparity in relative "electronegativities" increases it should approach 100 : 0. An abbreviated series of radicals in the order of decreasing "electronegativity" on the Kharasch scale follows: $p\text{-CH}_3\text{OC}_6\text{H}_4 > p\text{-CH}_3\text{C}_6\text{H}_4 > \text{C}_6\text{H}_5 > \text{H}_2\text{C}=\text{CH}^* > \text{CH}_3 > \text{C}_2\text{H}_5 > i\text{-C}_3\text{H}_7 > \text{C}_6\text{H}_5\text{CH}_2 > t\text{-C}_4\text{H}_9$.

That upon the primary electronic effect thus hypothesized there may be superimposed a relatively minor secondary effect is suggested by the case of the heterotrisubstituted oxirane 1-phenyl-2-methyl-1,2-epoxypropane. Although it might be inferred from the above "electronegativity" series that one phenyl radical is slightly more effective than two methyl

²⁸Concerning the electronegativity theory and the relative electronegativities of organic radicals, see: Kharasch and Reinmuth, *J. Chem. Education*, 5, 404-18 (1928); 8, 1703-48 (1931); Kharasch, Reinmuth, and Mayo, *ibid.*, 11, 82-96 (1934); 13, 7-19 (1936).

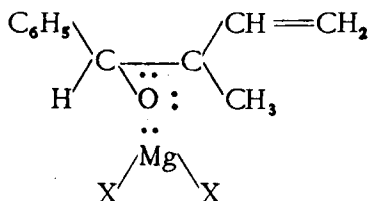
*The relative "electronegativities" of groups capable of associating a proton cannot be determined experimentally by the Kharasch technique [see Kharasch and Swartz, *J. Org. Chem.*, 3, 405-8 (1938)]. A considerable variety of qualitative chemical evidence, however, suggests that the vinyl radical is probably very close to, but slightly lower than, the phenyl radical in "electronegativity."

radicals ($i\text{-C}_3\text{H}_7 > \text{C}_6\text{H}_5\text{CH}_2$) in decreasing the electron density about a substituted carbon atom, this epoxide when treated with magnesium bromide yields about 90 percent of α -methyl- α -phenylpropionaldehyde and only a little 3-phenylbutanone (Ref. 15).



Although it might be suggested that the methyl radical is a more potent substituent in olefinic and closely related systems than in the methane series, a more logical explanation would seem to be that the rearrangement is in fact a concerted coincidence, rather than a series, of processes, and that, whereas the substituent effect of a phenyl radical differs but little from that of two methyl radicals, the potential migratory aptitude of the phenyl group is considerably greater than that of a methyl group.

In many cases, however, as in that of 3-methyl-4-phenyl-3,4-epoxybutene (Ref. 14), the nature of the individual substituent radicals of the heterotrisubstituted oxirane leaves little doubt that the aggregate substituent effect of the *gem* substituents is materially greater than that of the lone substituent, and ring-opening takes place in the readily predictable direction.



That which we have arbitrarily chosen to call the second stage of the reaction is directed in part (but only in part) by the property which we have chosen to call the "potential migratory aptitude" of the transitive group. Here a definitive statement is in order. It is obvious from the foregoing discussion of the so-called first stage of the epoxide rearrangement that any attempt to establish an order of relative group migratory aptitudes by merely observing which group migrates in these or analogous (*e.g.*, pinacol, hydrobenzoin) rearrangements is foredoomed to encounter the most embarrassing inconsistencies. Superficially it might appear that having duly regarded the so-called first stage of the reaction, and having thus automatically eliminated from consideration half of the potential migrants, it might be possible to establish an order of migratory aptitudes by observing, in a sufficient number of cases, which of two remaining eligible groups actually does migrate. Analogous observations have

been made in the closely related rearrangements of symmetrical pinacols of the type $[\text{ArAr}'\text{C}(\text{OH})—]_2$, notably by Bachmann.²⁹

It is true that in this manner much more self-consistent orderings of groups can be attained, and that upon them much more reliable predictions of group behavior can be based. It is to the property (or, to be more precise, the combination of properties) involved that Wheland has chosen to apply the term "intrinsic migratory aptitude." In the opinion of the present authors this choice is unfortunate because the migratory behavior of a group in such rearrangements is dependent on properties not exclusively its own. A better term would be "effective migratory aptitude" (with reference to a specific reaction).

To particularize, a group migration involves both a "take-off" and a "landing." It is only for the first of these that aptitude can be related to an intrinsic property of the migratory group. Whereas these rearrangements involve the transfer of a pair of electrons from the *beta* to the *alpha* carbon atom, it follows that the group which has the greater tendency to accompany the electron pair is the more "electronegative" of the two potential migrants. It is to this tendency that the present authors would have preferred to apply the term "intrinsic migratory aptitude"; for second choice, they adopt the term "potential migratory aptitude."

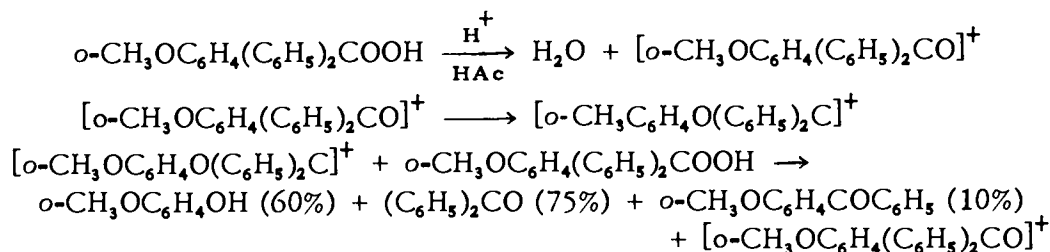
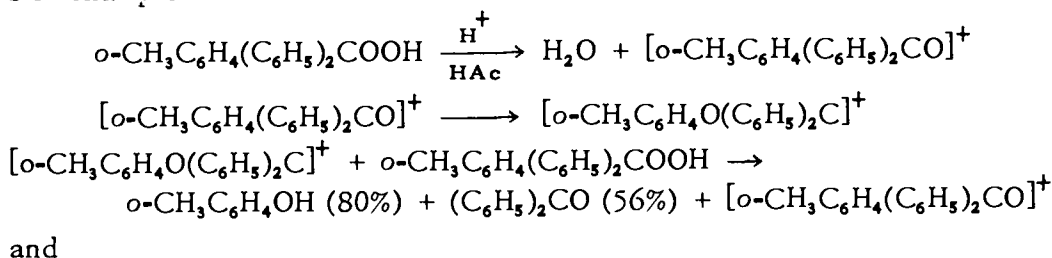
However, *effective* migratory aptitude entails facility in both "take-off" and "landing." The latter is determined by what may be loosely called the relative "sizes" of the migrant and the "landing-field." In more conventional, though less specific, language, the course of such a process is so strongly influenced by steric factors that energetic factors are often reduced to a secondary (and sometimes a negligible) rôle. This accounts for the relatively high effective migratory aptitude of hydrogen (which must have a relatively low potential migratory aptitude), and for the relatively low effective migratory aptitudes of the *m*- and *o*-anisyl groups (which must have nearly as high potential migratory aptitudes as has the *p*-anisyl group).

Parenthetically, the working hypothesis proposed implies that if steric screening of the "landing-field" could be eliminated or minimized the *effective* migratory aptitude of a group (with respect to the test reaction) would equal or approximate its true *potential* migratory aptitude. The prescribed condition is met, or closely approached, in rearrangements of carbonium ions of the types $[\text{RR}'\text{R}''\text{CO}]^+$ and $[\text{RR}'_2\text{CO}]^+$, generated in the acid-catalyzed decompositions of tertiary aralkyl hydroperoxides, and the course of rearrangement is consistent with the implication stated, as has been demonstrated by Kharasch *et al.*³⁰

²⁹Bachmann and Moser, *J. Am. Chem. Soc.*, 54, 1124-33 (1932); Bachmann and Ferguson, *ibid.*, 56, 2081-4 (1934). See also: Wheland, *op. cit.*,²⁷ p. 515; Adkins, Chapter 13 of Volume I of Gilman's "Organic Chemistry," John Wiley & Sons, Inc., New York, 2nd ed., 1943, p. 1067; Wallis, Chapter 12 of Volume I of Gilman's "Organic Chemistry," p. 969.

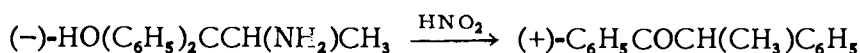
³⁰Kharasch, Fono, Nudenberg, and Poshkus, *J. Org. Chem.*, 15, 775-81 (1951).

For example:

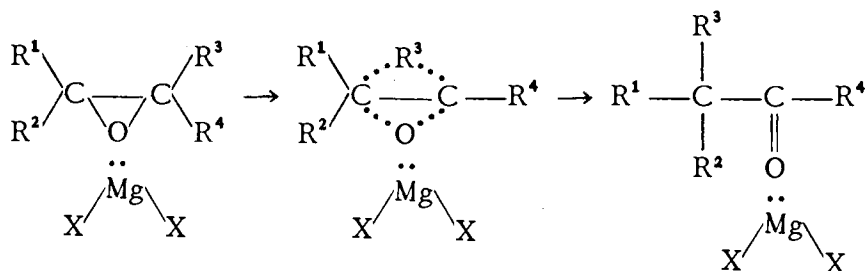


All such working hypotheses relating to relative migratory aptitudes implicitly presuppose that the preferred migration shall yield a stable, or readily stabilizable, product or intermediate. When this is not the case, the less-favored migration may yield a stable product that is superficially misleading [*cf.* Kharasch *et al.*³¹ concerning the dehydration-rearrangement of $\text{HO}(\text{C}_6\text{H}_5)_2\text{CC}(\text{CH}_3)_2\text{C}_6\text{H}_5$].

Incidentally, it may here be noted that rearrangements of the general 1,2 carbon-to-carbon type under discussion all presumably involve a Walden inversion of the *alpha* carbon atom. In one case of semipinacolic deamination the *vic* amino alcohol and corresponding ketone have been shown to be of opposite configurations.³²



This retention of optical activity (with inversion) argues strongly in favor of a reaction mechanism involving a concerted coincidence of processes rather than a more or less disconnected sequence of processes. Such a mechanism might be schematically represented as follows.



To the further confusion of lovers of the simple solution and the easy generalization it has recently been realized (and demonstrated) that compounds in which both the *alpha* and the *beta* carbon atoms are asymmetric may undergo stereospecific rearrangement (at least in some degree).

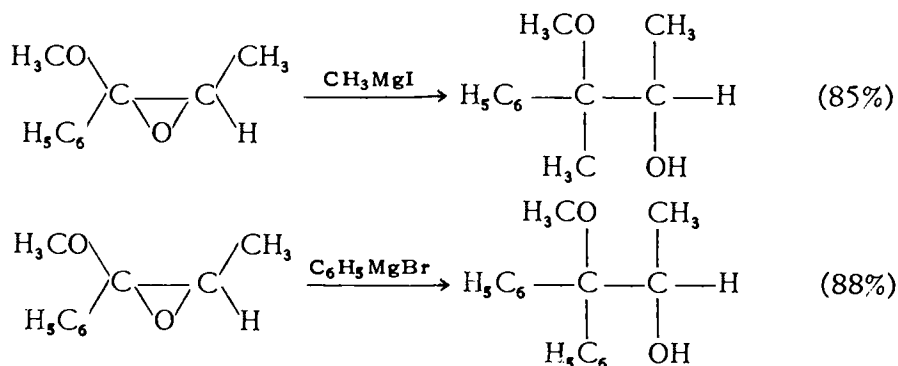
³¹ Kharasch, Poshkus, Fono, and Nudenberg, *J. Org. Chem.*, 16, 1458-70 (1951).

³² Bernstein and Whitmore, *J. Am. Chem. Soc.*, 61, 1324-6 (1939).

of ring-opening may be treated independently of the question of the natures of the migratory group and of the locus of its ultimate attachment. Unfortunately no such simplification is possible in attempts to predict the courses of the Grignard addition reactions of unsymmetrical epoxides.

From a purely electronic standpoint it would appear that the relatively electron-deficient oxirane carbon atom should be the more disposed to become the *alpha* carbon, both because of its greater potential susceptibility to nucleophilic attack and its greater tendency to release the oxirane oxygen and its octet of electrons. However, the experimental data (see Table XIV-I) indicate that in the cases of α -epichlorohydrin, propylene oxide, α -butylene oxide, isobutylene oxide, and 2-methyl-2,3-epoxybutane, the direction of ring-opening and the point of attachment of the entering group are precisely the opposite of those to be expected on such grounds. This might suggest that the true directive influence is steric were it not for the fact that additions to styrené oxide take place (at least predominantly) in the electronically-indicated direction. Tentatively, then, the present authors conclude that when the differences in the electronic states of the two oxirane carbon atoms are small or moderate, steric influences may overshadow (or completely negate) them, and the entering group will attach to the less obstructed carbon atom. When the difference in electronic states is sufficiently great it will tend to overcome relatively small opposing differences in steric effect.

The observations of Stevens and Pratt^{34.1} and of Temnikova and Kropacheva^{34.2} regarding the behavior of 1-methoxy-1-phenyl-1,2-epoxypropane indicate that a sufficient degree of polarity in the oxirane ring system may overcome a relatively high degree of steric inhibition.

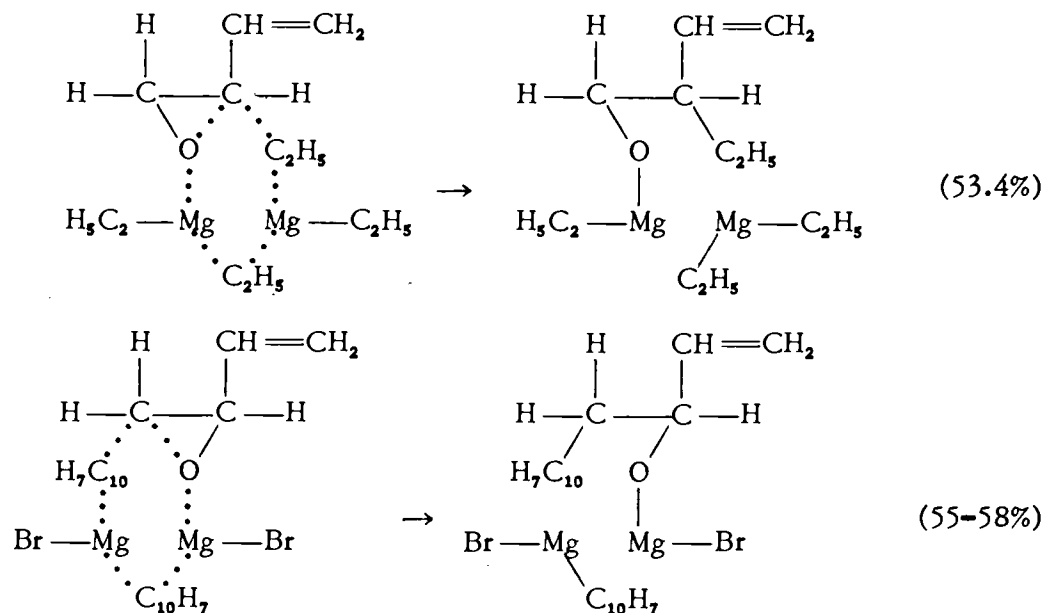


It goes without saying, of course, that the foregoing discussion relates to *predominant* rather than *exclusive* product formation. Undoubtedly, sufficiently skillful and careful reëxamination of many of the reactions recorded in Table XIV-I would reveal the formation of two addition products where only one is now reported.

^{34.1}Stevens and Pratt, Abstracts of Papers, 119th Meeting, A.C.S., Cleveland, Ohio, April, 1951, p. 92M.

^{34.2}Temnikova and Kropacheva, *J. Gen. Chem. (U.S.S.R.)*, 21, 183-6 (1951); *Chem. Abstr.*, 45, 7046 (1951).

It may not be amiss to reiterate the fact that the steric effect reflects a composite of the properties of the *alpha* oxirane carbon atom (with its substituents) and the entering group. If the existent data are in fact as reliable as they appear, 3,4-epoxy-1-butene, in its reactions with diethylmagnesium³⁵ and 1-naphthylmagnesium bromide,³⁶ respectively, provides an interesting and cogent illustration. Although both Grignard reagents participate to some extent in "1,4-addition"^{35,36b} (*q.v.*), the former, with the relatively small entering group, follows the electronically-indicated course in "normal" addition, whereas the latter, with the relatively large entering group, follows the sterically-indicated course.*



1,4-ADDITION

Addition reactions formally analogous to the 1,4-addition reactions of α,β -unsaturated ketones (*q.v.*) have been reported for 3,4-epoxy-1-butene with: ethylmagnesium bromide (31 percent) and diethylmagnesium (17 percent);³⁵ for methylmagnesium iodide (36 percent), phenylmagnesium bromide (38 percent), cyclohexylmagnesium chloride (34 percent), 2-ethoxyphenylmagnesium bromide (15 percent), and 1-naphthylmagnesium bromide (30 percent);^{36b} and for 2-thienylmagnesium bromide (26 percent).³⁷

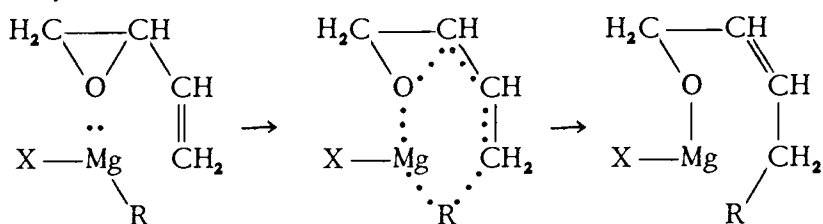
³⁵Freedman and Becker, *J. Org. Chem.*, 16, 1701-11 (1951).

³⁶(a) Gaylord and Becker, *J. Org. Chem.*, 15, 305-16 (1950); (b) Semeniuk and Jenkins, *J. Am. Pharm. Assoc., Sci. Ed.*, 37, 118-21 (1948); *Chem. Abstr.*, 42, 5410 (1948).

*It should be noted in passing that the two studies cited^{36a,b} are not strictly comparable with each other, nor with the study on styrene oxide,²⁵ by reason of the limited ether-solubility of α -naphthylmagnesium bromide. A better choice of reaction medium or of Grignard reagent should yield data of higher critical value.

³⁷Gmitter and Benton, *J. Am. Chem. Soc.*, 72, 4586-9 (1950).

By analogy it might be postulated that, whereas the ordinary additions are probably trimolecular, the 1,4-additions are probably bimolecular.



It would be interesting to learn whether or not the proportion of 1,4-addition could be materially altered by reversal of the order of reagent addition, and also whether or not cuprous chloride would facilitate the 1,4-addition as it does in the case of the α,β -unsaturated ketones.

PREPARATIVE PROCEDURES

Only the reactions of ethylene oxide with Grignard reagents may be said to have been developed into a general preparative method. The preparation of octanol, here described, has been employed by Vaughn *et al.*³⁸ for several other alkanols: hexanol (59 percent), heptanol (58 percent), nonanol (55 percent), decanol (52 percent). A somewhat similar method which does not employ liquid-ammonia cooling is described by Dreger³⁹ for hexanol (60-62 percent).

"A solution of 330 g. of hexyl bromide in 700 ml. of ether was added in the usual manner to 48 g. of magnesium turnings contained in a 2-liter 3-necked flask fitted with dropping funnel, mercury-sealed stirrer, and reflux condenser. As soon as the reaction was completed (thirty to forty-five minutes) the flask was placed in an ice-salt bath, and the reflux condenser was replaced by a liquid-ammonia-cooled spiral condenser.⁴⁰ The dropping funnel was replaced by an inlet tube reaching almost to the surface of the liquid, and 95 g. of ethylene oxide was added as rapidly (forty-five to sixty minutes) as the vigorous refluxing permitted. The cooling bath was removed, and, after refluxing ceased, 250 to 275 ml. of ether was removed by distillation from a water-bath. Three hundred thirty ml. of dry benzene was added, and the distillation was continued without interruption of stirring until the temperature of the effluent vapor reached 65°. The mixture was then refluxed for one hour, and was hydrolyzed with ice-cold 10% sulfuric acid. The benzene layer was separated and washed twice with 10% sodium hydroxide solution. The benzene was removed by distillation, and the residue was fractionated under reduced pressure. The yield was 185 g. (71%) of material boiling at 105° at fifteen mm."

³⁸Vaughn, Spahr, and Nieuwland, *J. Am. Chem. Soc.*, 55, 4206-9 (1933).

³⁹Dreger, *Organic Syntheses*, 6, 54-7 (1926); Coll. Vol. I, 1st ed., 298-301 (1932); 2nd ed., 306-8 (1941).

⁴⁰Vaughn and Pozzi, *J. Chem. Education*, 8, 2433-4 (1931).

A slightly different technique, employed by Bachman and Thomas⁴¹ in the preparation of 2-*m*-anisylethanol is described as follows.

"A solution of 46.8 g. of *m*-iodoanisole and 21.8 g. of ethyl bromide in 75 ml. of ether was added in portions to 10.7 g. of ground magnesium and 125 ml. of ether in a three-necked flask equipped with condenser, dropping funnel and mercury-seal stirrer. When the addition was complete (about forty-five minutes), 100 ml. of benzene was added, and the mixture was refluxed for an hour. Another 100 ml. of benzene was then added, and refluxing was continued for four or five hours. The mixture was cooled to 5°, and ethylene oxide gas, after being passed first over soda lime and then [over] potassium hydroxide pellets, was led to within an inch of the surface of the stirred mixture. When 30 g. of ethylene oxide had been added, the entire contents of the flask set to a gelatinous solid. After standing for two hours (or overnight), the mixture was refluxed for three or four hours, during which time most of the solid disappeared. The mixture was cooled to 5°, and, after addition of 6 g. more of ethylene oxide, gelation again occurred. After standing an hour, the mixture was refluxed for an hour and a half, then cooled, hydrolyzed, and worked up in the usual manner.

"The product was fractionated under reduced pressure. A forerun up to 110° was discarded, and the main fraction was collected from 110–150° at 12 mm.; most of it boiled within the range 143–150°. The yield of β -*m*-anisylethyl alcohol suitable for conversion to the bromide was 25.8 g. (85%)."

⁴¹Bachman and Thomas, *J. Am. Chem. Soc.*, 64, 94–7 (1942).

TABLE XIV-I
REACTIONS OF GRIGNARD REAGENTS WITH EPOXIDES

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O			
(CH ₂) ₂ O	C ₂ H ₅ MgCl (1.0 equiv.)	<i>n</i> -C ₄ H ₉ OH (54.6%); ClCH ₂ CH ₂ OH (22%)*	71
(CH ₂) ₂ O	C ₂ H ₅ MgCl (1.0 equiv.)	<i>n</i> -C ₄ H ₉ OH (45.9%); ClCH ₂ CH ₂ OH (16.4%)†	71
(CH ₂) ₂ O	C ₂ H ₅ MgCl (0.5 equiv.)	<i>n</i> -C ₄ H ₉ OH (80.3%); ClCH ₂ CH ₂ OH (69.4%)‡	71
(CH ₂) ₂ O	RMgBr§	RCH ₂ CH ₂ OH;§ BrCH ₂ CH ₂ OH	12
(CH ₂) ₂ O (15 g.)	C ₂ H ₅ MgBr (0.5 equiv.)	<i>n</i> -C ₄ H ₉ OH (82.6%)	53,58,95
(CH ₂) ₂ O	C ₂ H ₅ MgBr (1.0 equiv.)	<i>n</i> -C ₄ H ₉ OH (79%);¶ BrCH ₂ CH ₂ OH (11%)||	68
(CH ₂) ₂ O	C ₂ H ₅ MgBr (1.0 equiv.)	<i>n</i> -C ₄ H ₉ OH (72%);¶ BrCH ₂ CH ₂ OH (45%)||	68
(CH ₂) ₂ O	CH ₃ C≡CMgBr	CH ₃ C≡CCH ₂ CH ₂ OH (95%)	76
(CH ₂) ₂ O	<i>n</i> -C ₃ H ₇ MgCl (1.0 equiv.)	<i>n</i> -C ₅ H ₁₁ OH (39.5%); ClCH ₂ CH ₂ OH (31.5%)*	71
(CH ₂) ₂ O	<i>n</i> -C ₃ H ₇ MgCl (1.0 equiv.)	<i>n</i> -C ₅ H ₁₁ OH (49.9%); ClCH ₂ CH ₂ OH (32.0%)†	71
(CH ₂) ₂ O	<i>n</i> -C ₃ H ₇ MgCl (0.5 equiv.)	<i>n</i> -C ₅ H ₁₁ OH (66.4%); ClCH ₂ CH ₂ OH (54.0%)‡	71
(CH ₂) ₂ O	<i>n</i> -C ₃ H ₇ MgBr (1.0 equiv.)	<i>n</i> -C ₅ H ₁₁ OH (76%)¶ BrCH ₂ CH ₂ OH (6%)||	68
(CH ₂) ₂ O	<i>n</i> -C ₃ H ₇ MgBr (0.5 equiv.)	<i>n</i> -C ₅ H ₁₁ OH (75%);¶ BrCH ₂ CH ₂ OH (43%)||	68
(CH ₂) ₂ O (132 g.)	<i>i</i> -C ₃ H ₇ MgCl (236 g. C ₃ H ₇ Cl)	<i>i</i> -C ₅ H ₁₁ OH (160 g., 60%)	137
(CH ₂) ₂ O	<i>i</i> -C ₃ H ₇ MgCl (1.0 equiv.)	<i>i</i> -C ₅ H ₁₁ OH (34.5%); ClCH ₂ CH ₂ OH (35.1%)*	71
(CH ₂) ₂ O	<i>i</i> -C ₃ H ₇ MgCl (1.0 equiv.)	<i>i</i> -C ₅ H ₁₁ OH (46.5%); ClCH ₂ CH ₂ OH (19.5%)†	71
(CH ₂) ₂ O	<i>i</i> -C ₃ H ₇ MgCl (0.5 equiv.)	<i>i</i> -C ₅ H ₁₁ OH (54.8%); ClCH ₂ CH ₂ OH (58.0%)‡	71

* Slow addition of Dry Ice-cooled Et₂O-epoxide solution to ice-salt-cooled Grignard reagent solution; one hour stirring without cooling under N₂.

† Slow addition of Dry Ice-cooled Et₂O-epoxide solution to ice-salt-cooled Grignard reagent solution; partial distillation of Et₂O; addition of C₆H₆; six hours reflux under N₂.

‡ Slow addition of Dry Ice-cooled Et₂O-epoxide solution to ice-salt-cooled Grignard reagent solution under N₂. Yields are calculated on the basis of the postulated reactions: R₂Mg + 2 (CH₂)₂O → (RCH₂CH₂O)₂Mg and MgCl₂ + 2 (CH₂)₂O → (ClCH₂CH₂O)₂Mg.

§ According to Grignard (53), R = C₂H₅.

¶ Yield of alcohol calculated on the basis of (CH₂)₂O.

|| Yield of halohydrin calculated on the basis of halide (RX) used in preparation of the Grignard reagent (RMgX).

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O (cont.)			
(CH ₂) ₂ O	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₈ H ₁₁ OH (30%)	102,34
(CH ₂) ₂ O	<i>i</i> -C ₃ H ₇ MgBr (1.0 equiv.)	<i>i</i> -C ₈ H ₁₁ OH (74%); * BrCH ₂ CH ₂ OH (7%) [†]	68
(CH ₂) ₂ O	<i>i</i> -C ₃ H ₇ MgBr (0.5 equiv.)	<i>i</i> -C ₈ H ₁₁ OH (70%); * BrCH ₂ CH ₂ OH (45%) [†]	68
(CH ₂) ₂ O	H ₂ C=CHC≡CMgBr	H ₂ C=CHC≡CCH ₂ CH ₂ OH (20%); BrCH ₂ CH ₂ OH (55%)	97
(CH ₂) ₂ O (44.0 g., 1 mole)	2-Thienyl-MgBr (81.5 g., 0.5 mole C ₄ H ₃ BrS)	2-Thiopheneethanol (33.6 g., 53%)	193
(CH ₂) ₂ O (20.0 g.)	C ₂ H ₅ C≡CMgBr (15.0 g. C ₄ H ₆)	C ₂ H ₅ C≡CCH ₂ CH ₂ OH (7.6 g.); BrCH ₂ CH ₂ OH (14.0 g.)	127
(CH ₂) ₂ O	<i>n</i> -C ₄ H ₉ MgCl (1.0 equiv.)	<i>n</i> -C ₆ H ₁₃ OH (39.0%); ClCH ₂ CH ₂ OH (25.5%) [‡]	71
(CH ₂) ₂ O	<i>n</i> -C ₄ H ₉ MgCl (1.0 equiv.)	<i>n</i> -C ₆ H ₁₃ OH (45.8%); ClCH ₂ CH ₂ OH (36.8%) [§]	71
(CH ₂) ₂ O	<i>n</i> -C ₄ H ₉ MgCl (0.5 equiv.)	<i>n</i> -C ₆ H ₁₃ OH (69.6%); ClCH ₂ CH ₂ OH (60.1%) [¶]	71
(CH ₂) ₂ O (278 g.)	<i>n</i> -C ₄ H ₉ MgBr (822 g. C ₄ H ₉ Br)	<i>n</i> -C ₆ H ₁₃ OH (368–380 g., 60–62%)	31,26,102, 134
(CH ₂) ₂ O	<i>n</i> -C ₄ H ₉ MgBr (1.0 equiv.)	<i>n</i> -C ₆ H ₁₃ OH (70%); * BrCH ₂ CH ₂ OH (5%) [†]	68
(CH ₂) ₂ O	<i>n</i> -C ₄ H ₉ MgBr (0.5 equiv.)	<i>n</i> -C ₆ H ₁₃ OH (71%); * BrCH ₂ CH ₂ OH (41%) [†]	68
(CH ₂) ₂ O (500 g., 11.33 moles)	(<i>n</i> -C ₄ H ₉) ₂ Mg (4.2 moles)	<i>n</i> -C ₆ H ₁₃ OH (373 g., 43.5%); CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (7 g.)	26

*Yield of alcohol calculated on the basis of (CH₂)₂O.

[†]Yield of halohydrin calculated on the basis of halide (RX) used in preparation of the Grignard reagent (RMgX).

[‡]Slow addition of Dry Ice-cooled Et₂O-epoxide solution to ice-salt-cooled Grignard reagent solution; one hour stirring without cooling under N₂.

[§]Slow addition of Dry Ice-cooled Et₂O-epoxide solution to ice-salt-cooled Grignard reagent solution; partial distillation of Et₂O; addition of C₆H₆; six hours reflux under N₂.

[¶]Slow addition of Dry Ice-cooled Et₂O-epoxide solution to ice-salt-cooled Grignard reagent solution under N₂. Yields are calculated on the basis of the postulated reactions: R₂Mg + 2 (CH₂)₂O → (RCH₂CH₂O)₂Mg and MgCl₂ + 2 (CH₂)₂O → (ClCH₂CH₂O)₂Mg.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O (<i>cont.</i>)			
(CH ₂) ₂ O	<i>i</i> -C ₄ H ₉ MgCl (1.0 equiv.)	<i>i</i> -C ₆ H ₁₃ OH (23.6%); Cl ₂ CH ₂ CH ₂ OH (34.6%)*	71
(CH ₂) ₂ O	<i>i</i> -C ₄ H ₉ MgCl (1.0 equiv.)	<i>i</i> -C ₆ H ₁₃ OH (29.8%); ClCH ₂ CH ₂ OH (25.0%)†	71
(CH ₂) ₂ O	<i>i</i> -C ₄ H ₉ MgCl (0.5 equiv.)	<i>i</i> -C ₆ H ₁₃ OH (35.2%); ClCH ₂ CH ₂ OH (60.4%)‡	71
(CH ₂) ₂ O	<i>i</i> -C ₄ H ₉ MgBr	<i>i</i> -C ₆ H ₁₃ OH (30-40%)	34,102,183
(CH ₂) ₂ O	<i>i</i> -C ₄ H ₉ MgBr (1.0 equiv.)	<i>i</i> -C ₆ H ₁₃ OH (64%);§ BrCH ₂ CH ₂ OH (3%)¶	68
(CH ₂) ₂ O	<i>i</i> -C ₄ H ₉ MgBr (0.5 equiv.)	<i>i</i> -C ₆ H ₁₃ OH (69%);§ BrCH ₂ CH ₂ OH (41%)¶	68
(CH ₂) ₂ O	<i>s</i> -C ₄ H ₉ MgCl (1.0 equiv.)	<i>s</i> -C ₄ H ₉ CH ₂ CH ₂ OH (25.6%); ClCH ₂ CH ₂ OH (30.9%)*	71
(CH ₂) ₂ O	<i>s</i> -C ₂ H ₅ MgCl	<i>s</i> -C ₄ H ₉ CH ₂ CH ₂ OH (35.1%); ClCH ₂ CH ₂ OH (23.9%)†	71
(CH ₂) ₂ O	<i>s</i> -C ₄ H ₉ MgCl (0.5 equiv.)	<i>s</i> -C ₄ H ₉ CH ₂ CH ₂ OH (40.9%); ClCH ₂ CH ₂ OH (61.5%)‡	71
(CH ₂) ₂ O	<i>s</i> -C ₄ H ₉ MgBr	<i>s</i> -C ₄ H ₉ CH ₂ CH ₂ OH (36%)	102
(CH ₂) ₂ O	<i>s</i> -C ₄ H ₉ MgBr (1.0 equiv.)	<i>s</i> -C ₄ H ₉ CH ₂ CH ₂ OH (65%);§ BrCH ₂ CH ₂ OH (9%)¶	68
(CH ₂) ₂ O	<i>s</i> -C ₄ H ₉ MgBr (0.5 equiv.)	<i>s</i> -C ₄ H ₉ CH ₂ CH ₂ OH (65%);§ BrCH ₂ CH ₂ OH (51%)¶	68
(CH ₂) ₂ O (15 g.)	<i>t</i> -C ₄ H ₉ MgCl (31 g. C ₄ H ₉ Cl)	<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ OH (13.2%)	91

* Slow addition of Dry Ice-cooled Et₂O-epoxide solution to ice-salt-cooled Grignard reagent solution; one hour stirring without cooling under N₂.

† Slow addition of Dry Ice-cooled Et₂O-epoxide solution to ice-salt-cooled Grignard reagent solution; partial distillation of Et₂O; addition of C₆H₆; six hours reflux under N₂.

‡ Slow addition of Dry Ice-cooled Et₂O-epoxide solution to ice-salt-cooled Grignard reagent solution under N₂. Yields are calculated on the basis of the postulated reactions: R₂Mg + 2 (CH₂)₂O → (RCH₂CH₂O)₂Mg and MgCl₂ + 2 (CH₂)₂O → (ClCH₂CH₂O)₂Mg.

§ Yield of alcohol calculated on the basis of (CH₂)₂O.

¶ Yield of halohydrin calculated on the basis of halide (RX) used in preparation of the Grignard reagent (RMgX).

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O (<i>cont.</i>)			
(CH ₂) ₂ O	<i>t</i> -C ₄ H ₉ MgCl (1.0 equiv.)	<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ OH (0.0%); ClCH ₂ CH ₂ OH (21.3%)*	71
(CH ₂) ₂ O	<i>t</i> -C ₄ H ₉ MgCl (1.0 equiv.)	<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ OH (0.0%); ClCH ₂ CH ₂ OH (23.3%)†	71
(CH ₂) ₂ O	<i>t</i> -C ₄ H ₉ MgCl (0.5 equiv.)	<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ OH (0.0%); ClCH ₂ CH ₂ OH (48.1%)‡	71
(CH ₂) ₂ O	<i>t</i> -C ₄ H ₉ MgBr (1.0 equiv.)	BrCH ₂ CH ₂ OH (60%)§	68
(CH ₂) ₂ O	<i>t</i> -C ₄ H ₉ MgBr (0.5 equiv.)	<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ OH (9%);¶ BrCH ₂ CH ₂ OH (50%)§	68
(CH ₂) ₂ O (10 moles)	(CH ₃) ₃ SiCH ₂ MgCl (5 moles C ₄ H ₁₁ ClSi)	(CH ₃) ₃ Si(CH ₂) ₃ OH (468 g., 3.57 moles)	188
(CH ₂) ₂ O (52 g.)	H ₂ C=C(CH ₃)C≡CMgBr (109 g. C ₂ H ₅ Br)	H ₂ C=C(CH ₃)C≡CCH ₂ CH ₂ OH (25 g.); BrCH ₂ CH ₂ OH (51 g.)	97
(CH ₂) ₂ O (26.4 g., 0.6 mole)	2-Thenyl-MgBr (0.241 mole)	2-Methyl-3-thiopheneethanol (13.5 g., 39%)	194
(CH ₂) ₂ O	<i>n</i> -C ₃ H ₇ C≡CMgBr	<i>n</i> -C ₃ H ₇ C≡CCH ₂ CH ₂ OH (<i>ca.</i> 30%)	195
(CH ₂) ₂ O	(CH ₂) ₄ CHMgCl	(CH ₂) ₄ CHCH ₂ CH ₂ OH (27%)	177
(CH ₂) ₂ O	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₇ H ₁₅ OH (58%)	134
(CH ₂) ₂ O	<i>n</i> -C ₅ H ₁₁ MgBr (1.0 equiv.)	<i>n</i> -C ₇ H ₁₅ OH (69%);¶ BrCH ₂ CH ₂ OH (10%)§	68
(CH ₂) ₂ O	<i>n</i> -C ₅ H ₁₁ MgBr (0.5 equiv.)	<i>n</i> -C ₇ H ₁₅ OH (60%);¶ BrCH ₂ CH ₂ OH (40%)§	68

* Slow addition of Dry Ice-cooled Et₂O-epoxide solution to ice-salt-cooled Grignard reagent solution; one hour stirring without cooling under N₂.

† Slow addition of Dry Ice-cooled Et₂O-epoxide solution to ice-salt-cooled Grignard reagent solution; partial distillation of Et₂O; addition of C₆H₆; six hours reflux under N₂.

‡ Slow addition of Dry Ice-cooled Et₂O-epoxide solution to ice-salt-cooled Grignard reagent solution under N₂. Yields are calculated on the basis of the postulated reactions: R₂Mg + 2 (CH₂)₂O → (RCH₂CH₂O)₂Mg and MgCl₂ + 2 (CH₂)₂O → (ClCH₂CH₂O)₂Mg.

§ Yield of halohydrin calculated on the basis of halide (RX) used in preparation of the Grignard reagent (RMgX).

¶ Yield of alcohol calculated on the basis of (CH₂)₂O.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O (<i>cont.</i>)			
(CH ₂) ₂ O (17 g.)	<i>i</i> -C ₈ H ₁₁ MgBr (0.5 equiv.)	<i>i</i> -C ₇ H ₁₅ OH (75%)	53,52
(CH ₂) ₂ O	<i>i</i> -C ₈ H ₁₁ MgBr (1.0 equiv.)	<i>i</i> -C ₇ H ₁₅ OH (59%); * BrCH ₂ CH ₂ OH (4%) [†]	68
(CH ₂) ₂ O	<i>i</i> -C ₈ H ₁₁ MgBr (0.5 equiv.)	<i>i</i> -C ₇ H ₁₅ OH (56%); * BrCH ₂ CH ₂ OH (41%) [†]	68
(CH ₂) ₂ O	<i>s</i> -C ₄ H ₉ CH ₂ MgBr (1.0 equiv.)	<i>s</i> -C ₄ H ₉ (CH ₂) ₃ OH (58%); * BrCH ₂ CH ₂ OH (9%) [†]	68
(CH ₂) ₂ O	<i>s</i> -C ₄ H ₉ CH ₂ MgBr (0.5 equiv.)	<i>s</i> -C ₄ H ₉ (CH ₂) ₃ OH (53%); * BrCH ₂ CH ₂ OH (35%) [†]	68
(CH ₂) ₂ O (15 g.)	<i>t</i> -C ₄ H ₉ CH ₂ MgBr (30 g. C ₅ H ₁₁ Br)	<i>t</i> -C ₄ H ₉ (CH ₂) ₃ OH (30%)	91
(CH ₂) ₂ O	CH ₃ (<i>n</i> -C ₃ H ₇)CHMgBr	CH ₃ (<i>n</i> -C ₃ H ₇)CHCH ₂ CH ₂ OH (28%)	21,102
(CH ₂) ₂ O	CH ₃ (<i>n</i> -C ₃ H ₇)CHMgBr (1.0 equiv.)	CH ₃ (<i>n</i> -C ₃ H ₇)CHCH ₂ CH ₂ OH (63%); * BrCH ₂ CH ₂ OH (5%) [†]	68
(CH ₂) ₂ O	CH ₃ (<i>n</i> -C ₃ H ₇)CHMgBr (0.5 equiv.)	CH ₃ (<i>n</i> -C ₃ H ₇)CHCH ₂ CH ₂ OH (50%); * BrCH ₂ CH ₂ OH (44%) [†]	68
(CH ₂) ₂ O	CH ₃ (<i>i</i> -C ₃ H ₇)CHMgBr (1.0 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHCH ₂ CH ₂ OH (40%); * BrCH ₂ CH ₂ OH (10%) [†]	68
(CH ₂) ₂ O	CH ₃ (<i>i</i> -C ₃ H ₇)CHMgBr (0.5 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHCH ₂ CH ₂ OH (46%); * BrCH ₂ CH ₂ OH (41%) [†]	68
(CH ₂) ₂ O	<i>t</i> -C ₅ H ₁₁ MgCl (1.0 equiv.)	ClCH ₂ CH ₂ OH (39%) [†]	68
(CH ₂) ₂ O	<i>t</i> -C ₅ H ₁₁ MgCl (0.5 equiv.)	ClCH ₂ CH ₂ OH (35%) [†]	68
(CH ₂) ₂ O	<i>t</i> -C ₅ H ₁₁ MgBr (1.0 equiv.)	BrCH ₂ CH ₂ OH (48%) [†]	68
(CH ₂) ₂ O	<i>t</i> -C ₅ H ₁₁ MgBr (0.5 equiv.)	BrCH ₂ CH ₂ OH (42%) [†]	68
(CH ₂) ₂ O (50 g.)	CH ₃ OCH ₂ CH(CH ₃)CH ₂ MgCl (1 mole C ₅ H ₁₁ ClO)	CH ₃ (CH ₃ OCH ₂)CH(CH ₂) ₃ OH (98 g., 74%)	158
(CH ₂) ₂ O	C ₆ H ₅ MgCl	C ₆ H ₅ CH ₂ CH ₂ OH (<i>ca.</i> 75%)	184,117, 169

* Yield of alcohol calculated on the basis of (CH₂)₂O.[†] Yield of halohydrin calculated on the basis of halide (RX) used in preparation of the Grignard reagent (RMgX).

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O (<i>cont.</i>)			
(CH ₂) ₂ O (99 g.)	C ₆ H ₅ MgCl* (72 g. Mg)	C ₆ H ₅ CH ₂ CH ₂ OH (185 g.); 4-C ₆ H ₅ C ₆ H ₄ CH ₂ CH ₂ OH; 4- (4-C ₆ H ₅ C ₆ H ₄)C ₆ H ₄ CH ₂ CH ₂ OH; 1,4-(C ₆ H ₅) ₂ C ₆ H ₄ ; (C ₆ H ₅ —) ₂	92
(CH ₂) ₂ O	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ CH ₂ OH	140,167, 187
(CH ₂) ₂ O	C ₆ H ₅ MgBr (1.0 equiv.)	C ₆ H ₅ CH ₂ CH ₂ OH (58%);† BrCH ₂ CH ₂ OH (42%)‡	68
(CH ₂) ₂ O	C ₆ H ₅ MgBr (0.5 equiv.)	C ₆ H ₅ CH ₂ CH ₂ OH (55%);† BrCH ₂ CH ₂ OH (50%)‡	68
(CH ₂) ₂ O	2-Pyridylmethyl-MgX§	3-(2-Pyridyl)-1-propanol	196
(CH ₂) ₂ O	<i>n</i> -C ₄ H ₉ C≡CMgBr	<i>n</i> -C ₄ H ₉ C≡CH (<i>ca.</i> 34%); BrCH ₂ CH ₂ OH (<i>ca.</i> 58%); <i>n</i> -C ₄ H ₉ C≡CCH ₂ CH ₂ OH (<i>ca.</i> 40%)¶	155
(CH ₂) ₂ O (70 g.)	(CH ₂) ₅ CHMgBr (163 g. C ₆ H ₁₁ Br)	(CH ₂) ₅ CHCH ₂ CH ₂ OH (56 g., 53%)	63,168
(CH ₂) ₂ O	(CH ₂) ₅ CHMgBr (1.0 equiv.)	(CH ₂) ₅ CHCH ₂ CH ₂ OH (50%);† BrCH ₂ CH ₂ OH (8%)‡	68
(CH ₂) ₂ O	(CH ₂) ₅ CHMgBr (0.5 equiv.)	(CH ₂) ₅ CHCH ₂ CH ₂ OH (45%);† BrCH ₂ CH ₂ OH (42%)‡	68
(CH ₂) ₂ O (95 g.)	<i>n</i> -C ₆ H ₁₃ MgBr (330 g. C ₆ H ₁₃ Br)	<i>n</i> -C ₆ H ₁₇ OH (185 g., 71%)	134
(CH ₂) ₂ O	<i>n</i> -C ₆ H ₁₃ MgBr (1.0 equiv.)	<i>n</i> -C ₆ H ₁₇ OH (49%);† BrCH ₂ CH ₂ OH (4%)‡	68
(CH ₂) ₂ O	<i>n</i> -C ₆ H ₁₃ MgBr (0.5 equiv.)	<i>n</i> -C ₆ H ₁₇ OH (47%);† BrCH ₂ CH ₂ OH (30%)‡	68
(CH ₂) ₂ O	<i>i</i> -C ₆ H ₁₃ MgBr	<i>i</i> -C ₆ H ₁₇ OH (60–65%)	34

* This Grignard reagent was prepared from Mg (72 g.) and C₆H₅Cl (1000 g.) without solvent other than the excess halide.

†Yield of alcohol calculated on the basis of (CH₂)₂O.

‡Yield of halohydrin calculated on the basis of halide (RX) used in preparation of the Grignard reagent (RMgX).

§X = Br, I.

¶Calculated on basis of Grignard reagent (RMgX) reacting.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O (<i>cont.</i>)			
(CH ₂) ₂ O (132 g.)	<i>t</i> -C ₄ H ₉ CH ₂ CH ₂ MgCl (362 g., C ₆ H ₁₃ Cl)	<i>t</i> -C ₄ H ₉ (CH ₂) ₄ OH (260 g., 67%)	186
(CH ₂) ₂ O	CH ₃ (<i>n</i> -C ₄ H ₉)CHMgBr (1.0 equiv.)	CH ₃ (<i>n</i> -C ₄ H ₉)CHCH ₂ CH ₂ OH (43%); * BrCH ₂ CH ₂ OH (6%) [†]	68
(CH ₂) ₂ O	CH ₃ (<i>n</i> -C ₄ H ₉)CHMgBr (0.5 equiv.)	CH ₃ (<i>n</i> -C ₄ H ₉)CHCH ₂ CH ₂ OH (40%); * BrCH ₂ CH ₂ OH (47%) [†]	68
(CH ₂) ₂ O	<i>n</i> -C ₃ H ₇ (CH ₃) ₂ CMgBr (1.0 equiv.)	BrCH ₂ CH ₂ OH (48%) [†]	68
(CH ₂) ₂ O	<i>n</i> -C ₃ H ₇ (CH ₃) ₂ CMgBr (0.5 equiv.)	BrCH ₂ CH ₂ OH (42%) [†]	68
(CH ₂) ₂ O (200 ml.)	(CH ₃) ₃ Si(CH ₂) ₃ MgBr (390 g. C ₆ H ₁₃ BrSi)	(CH ₃) ₃ Si(CH ₂) ₃ OH (206 g., 64%)	188
(CH ₂) ₂ O	3-F ₃ CC ₆ H ₄ MgBr (101.0 g., 0.45 mole C ₇ H ₄ BrF ₃)	3-F ₃ CC ₆ H ₄ CH ₂ CH ₂ OH (57.4 g., 67%)	2,191
(CH ₂) ₂ O (63 ml.)	2-BrC ₆ H ₄ CH ₂ MgBr (160 g. C ₇ H ₆ Br ₂)	2-BrC ₆ H ₄ CH ₂ CH ₂ OH (47%); (2-BrC ₆ H ₄ CH ₂ —) ₂ ; (2-HOCH ₂ CH ₂ - C ₆ H ₄ CH ₂ —) ₂	147
(CH ₂) ₂ O (35.0 g.)	3-F-4-CH ₃ OC ₆ H ₃ MgBr (79.5 g. C ₇ H ₆ BrFO)	3-F-4-CH ₃ OC ₆ H ₃ CH ₂ CH ₂ OH (35.0 g., 44%)	35
(CH ₂) ₂ O (excess)	C ₆ H ₅ CH ₂ MgCl (0.5 mole)	Oil (32.5 g., 47.8%, yielding upon oxid'n <i>ca.</i> equal wts. C ₆ H ₅ CO ₂ H and 1,4- (HO ₂ C) ₂ C ₆ H ₄)	164
(CH ₂) ₂ O	C ₆ H ₅ CH ₂ MgCl (1.0 equiv.)	C ₆ H ₅ (CH ₂) ₃ OH (73%); * ClCH ₂ CH ₂ OH (3%) [†]	68
(CH ₂) ₂ O	C ₆ H ₅ CH ₂ MgCl (0.5 equiv.)	C ₆ H ₅ (CH ₂) ₃ OH (79%); * ClCH ₂ CH ₂ OH (6%)	68
(CH ₂) ₂ O	4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ CH ₂ CH ₂ OH (55%)	55,140,187
(CH ₂) ₂ O (44 g.)	2-CH ₃ OC ₆ H ₄ MgBr (100 g. C ₇ H ₇ BrO)	2-CH ₃ OC ₆ H ₄ CH ₂ CH ₂ OH (54.5 g., 67%)	94
(CH ₂) ₂ O (35 g.)	3-CH ₃ OC ₆ H ₄ MgBr (120 g. C ₇ H ₇ BrO)	3-CH ₃ OC ₆ H ₄ CH ₂ CH ₂ OH (60 g.)	96,162
(CH ₂) ₂ O (36.0 g.)	3-CH ₃ OC ₆ H ₄ MgI (46.8 g. C ₇ H ₇ IO)	3-CH ₃ OC ₆ H ₄ CH ₂ CH ₂ OH (25.8 g., 85%)	3
(CH ₂) ₂ O	4-CH ₃ OC ₆ H ₄ MgBr (70 g. C ₇ H ₇ BrO)	4-CH ₃ C ₆ H ₄ CH ₂ CH ₂ OH (11 g.)	66,140,187

* Yield of alcohol calculated on the basis of (CH₂)₂O.

†Yield of halohydrin calculated on the basis of halide (RX) used in preparation of the Grignard reagent (RMgX).

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O (<i>cont.</i>)			
(CH ₂) ₂ O (1.5 equiv.)	<i>n</i> -C ₅ H ₁₁ C≡CMgBr	<i>n</i> -C ₅ H ₁₁ C≡CCH ₂ CH ₂ OH (<i>ca.</i> 40%)	33,28,4
(CH ₂) ₂ O (90 g.)	<i>n</i> -C ₈ H ₁₁ C≡CMgBr (192 g., 2 moles C ₇ H ₁₂)	<i>n</i> -C ₈ H ₁₁ C≡CH (65 g.); BrCH ₂ CH ₂ OH (95 g.); <i>n</i> -C ₅ H ₁₁ C≡CCH ₂ CH ₂ OH (60 g.)	155
(CH ₂) ₂ O (excess)	<i>n</i> -C ₇ H ₁₅ MgBr (179 g. C ₇ H ₁₅ Br)	<i>n</i> -C ₉ H ₁₉ OH (95 g., 65%)	93,134,90
(CH ₂) ₂ O	CH ₃ (<i>n</i> -C ₃ H ₇)CHCH ₂ CH ₂ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)CH(CH ₂) ₄ OH (65%)	21
(CH ₂) ₂ O (1.5 equiv.)	C ₆ H ₅ C≡CMgBr	C ₆ H ₅ C≡CCH ₂ CH ₂ OH (<i>ca.</i> 40%)	33,28,107
(CH ₂) ₂ O	C ₆ H ₅ C≡CMgBr	C ₆ H ₅ C≡CH (<i>ca.</i> 34%); BrCH ₂ CH ₂ OH (<i>ca.</i> 58%); C ₆ H ₅ C≡CCH ₂ CH ₂ OH (<i>ca.</i> 40%)	155
(CH ₂) ₂ O (2.2 g.)	Indolyl-MgX (5.5 g. C ₈ H ₇ N)	2-(β-Indolyl)ethanol (52%)	104; cf. 67
(CH ₂) ₂ O	2-CH ₃ C ₆ H ₄ CH ₂ MgBr	2,3-(CH ₃) ₂ C ₆ H ₃ CH ₂ CH ₂ OH (10x%); 3,4-(CH ₃) ₂ C ₆ H ₃ CH ₂ CH ₂ OH (90x%)	175
(CH ₂) ₂ O	3-CH ₃ C ₆ H ₄ CH ₂ MgBr	3-CH ₃ C ₆ H ₄ (CH ₂) ₃ OH (45%)	175
(CH ₂) ₂ O	4-CH ₃ C ₆ H ₄ CH ₂ MgBr	4-CH ₃ C ₆ H ₄ (CH ₂) ₃ OH (80x%); 2,3-(CH ₃) ₂ C ₆ H ₃ CH ₂ CH ₂ OH (20x%)	175
(CH ₂) ₂ O (4.5 ml.)	2,3-(CH ₃) ₂ C ₆ H ₃ MgBr (19.0 g. C ₆ H ₉ Br)	2,3-(CH ₃) ₂ C ₆ H ₃ CH ₂ CH ₂ OH	113
(CH ₂) ₂ O (100 g., 3.15 moles)	2-CH ₃ OCH ₂ C ₆ H ₄ MgBr (145 g. C ₈ H ₉ BrO)	2-CH ₃ OCH ₂ C ₆ H ₄ CH ₂ CH ₂ OH (64 g., 53%)	65
(CH ₂) ₂ O	2-CH ₃ O-4-CH ₃ C ₆ H ₃ MgBr	2-CH ₃ O-4-CH ₃ C ₆ H ₃ CH ₂ CH ₂ OH	140
(CH ₂) ₂ O (25 g.)	2-CH ₃ O-5-CH ₃ C ₆ H ₃ MgBr (86 g. C ₈ H ₉ BrO)	2-CH ₃ O-5-CH ₃ C ₆ H ₃ CH ₂ CH ₂ OH	25
(CH ₂) ₂ O (1.5 equiv.)	<i>n</i> -C ₆ H ₁₃ C≡CMgBr	<i>n</i> -C ₆ H ₁₃ C≡CCH ₂ CH ₂ OH (<i>ca.</i> 40%)	33
(CH ₂) ₂ O	(CH ₂) ₅ CHCH ₂ CH ₂ MgBr	(CH ₂) ₅ CH(CH ₂) ₄ OH (47-53%)	168
(CH ₂) ₂ O	(CH ₃) ₂ C=CHCH ₂ CH ₂ CH(CH ₃)MgBr	(CH ₃) ₂ C=CHCH ₂ CH ₂ CH(CH ₃)CH ₂ CH ₂ OH	129
(CH ₂) ₂ O	<i>n</i> -C ₈ H ₁₇ MgBr	<i>n</i> -C ₁₀ H ₂₁ OH (52%)	134
(CH ₂) ₂ O (10 ml.)	3-Thianaphthenylmethyl-MgCl (0.0405 mole)	3-(3-Thianaphthenyl)-1-propanol + 3-methyl-2-thianaphtheneethanol (aggregating 2.76 g., 35%)	197
(CH ₂) ₂ O	C ₆ H ₅ (CH ₂) ₃ MgBr (2 equiv.)	C ₆ H ₅ (CH ₂) ₃ OH (68%)	189,185
(CH ₂) ₂ O (6 g.)	3- <i>i</i> -C ₃ H ₇ C ₆ H ₄ MgBr (20 g. C ₉ H ₁₁ Br)	3- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ CH ₂ OH (8 g.)	54,13

TABLE XIV-I (Continued)

Epoxide	RMgX	Product(s)	Ref.
C₂H₄O (cont.)			
(CH ₂) ₂ O (9.0 g.)	2,3,4-(CH ₃) ₃ C ₆ H ₂ MgBr (11.2 g. C ₉ H ₁₁ Br)	2,3,4-(CH ₃) ₃ C ₆ H ₂ CH ₂ CH ₂ OH	119
(CH ₂) ₂ O (60. g., 1.36 mole)	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ MgBr (100 g., 0.46 mole C ₉ H ₁₁ BrO)	2-C ₂ H ₅ OCH ₂ C ₆ H ₄ CH ₂ CH ₂ OH (29 g., 35%)	64
(CH ₂) ₂ O	1-C ₁₀ H ₇ MgBr	1-C ₁₀ H ₇ CH ₂ CH ₂ OH (75%)	99,124,154
(CH ₂) ₂ O (5.5 g.)	2-C ₁₀ H ₇ MgBr (21.0 g. C ₁₀ H ₇ Br)	2-C ₁₀ H ₇ CH ₂ CH ₂ OH (11.6 g., 68%)	182,124
(CH ₂) ₂ O (0.75 mole)	C ₁₀ H ₁₇ MgCl* (0.5 mole)	C ₁₀ H ₁₇ CH ₂ CH ₂ OH†	14
(CH ₂) ₂ O	(CH ₂) ₅ CH(CH ₂) ₄ MgBr	(CH ₂) ₅ CH(CH ₂) ₆ OH (37%)	168
(CH ₂) ₂ O (18.5 ml.)	4-CH ₃ OC ₁₀ H ₆ -1-MgBr (70.0 g. C ₁₁ H ₉ BrO)	4-CH ₃ OC ₁₀ H ₆ -1-CH ₂ CH ₂ OH (22.0 g.)	108
(CH ₂) ₂ O (7.5 g.)	6-CH ₃ OC ₁₀ H ₆ -1-MgI (34.0 g. C ₁₁ H ₉ IO)	6-CH ₃ OC ₁₀ H ₆ -1-CH ₂ CH ₂ OH (12.5 g.)	153
(CH ₂) ₂ O	4-(CH ₂) ₄ CHC ₆ H ₄ MgBr	4-(CH ₂) ₄ CHC ₆ H ₄ CH ₂ CH ₂ OH	19
(CH ₂) ₂ O (30 g.)	2-CH ₃ -4- <i>t</i> -C ₄ H ₉ C ₆ H ₃ MgBr (115 g. C ₁₁ H ₁₅ Br)	2-CH ₃ -4- <i>t</i> -C ₄ H ₉ C ₆ H ₃ CH ₂ CH ₂ OH (60 g.)	17
(CH ₂) ₂ O	2-CH ₃ O-5- <i>t</i> -C ₄ H ₉ C ₆ H ₃ MgBr (120 g. C ₁₁ H ₁₅ BrO)	2-CH ₃ O-5- <i>t</i> -C ₄ H ₉ C ₆ H ₃ CH ₂ CH ₂ OH (50 g.)	17
(CH ₂) ₂ O (82.5 g.)	2,4,5-(CH ₃) ₃ -3,6-(CH ₃ O) ₂ C ₆ MgBr (55.0 g. C ₁₁ H ₁₅ BrO ₂)	2,4,5-(CH ₃) ₃ -3,6-(CH ₃ O) ₂ C ₆ CH ₂ CH ₂ OH (29.4 g., 62%)	122,120
(CH ₂) ₂ O (8.0 g.)	2-C ₆ H ₅ C ₆ H ₄ MgI (20.0 g. C ₁₂ H ₉ I)	2-C ₆ H ₅ C ₆ H ₄ CH ₂ CH ₂ OH (10.5 g., 76%)	156
(CH ₂) ₂ O (25 g.)	3-Acenaphthenyl-MgI (40 g. C ₁₂ H ₉ I)	2-(3-Acenaphthenyl)ethanol	23
(CH ₂) ₂ O (100.0 g., 2.28 moles)	4-C ₆ H ₅ OC ₆ H ₄ MgBr (294.0 g., 1.18 mole C ₁₂ H ₉ BrO)	4-C ₆ H ₅ OC ₆ H ₄ CH ₂ CH ₂ OH (133.4 g., 52%)	162
(CH ₂) ₂ O (1.9 g.)	4-CH ₃ O-6-CH ₃ C ₁₀ H ₅ -1-MgBr (8.8 g.)	4-CH ₃ O-6-CH ₃ C ₁₀ H ₅ -1-CH ₂ CH ₂ OH (4.6 g.)	86
(CH ₂) ₂ O (30 g.)	4-(CH ₂) ₅ CHC ₆ H ₄ MgBr (145 g. C ₁₂ H ₁₅ Br)	4-(CH ₂) ₅ CHC ₆ H ₄ CH ₂ CH ₂ OH (50 g.)	18

* From "pinene hydrochloride."

† "β-Camphanylethanol;" recovered as the acid phthalate (62 g.).

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₄O (<i>cont.</i>)			
(CH ₂) ₂ O (10.0 g.)	9-Phenanthryl-MgBr (48.5 g. C ₁₄ H ₉ Br)	(C ₁₄ H ₉)CH ₂ CH ₂ OH (15–21 g.)	148,178
(CH ₂) ₂ O (30 g.)	2-C ₆ H ₅ C ₆ H ₄ CH ₂ CH ₂ MgBr (33 g. C ₁₄ H ₁₃ Br)	2-C ₆ H ₅ C ₆ H ₄ (CH ₂) ₄ OH (11 g.)	156
(CH ₂) ₂ O (1.5 equiv.)	<i>n</i> -C ₁₁ H ₂₃ CH(CH ₃)(CH ₂) ₃ MgCl (57 g., 0.22 mole C ₁₆ H ₃₃ Cl)	CH ₃ (<i>n</i> -C ₁₁ H ₂₃)CH(CH ₂) ₃ OH (38.9 g., 66%)	150
C₃H₃OCl₃			
1,2-Epoxy-3,3,3-trichloropropane (21.0 g., 0.13 mole)	CH ₃ MgI (0.13 mole)	Cl ₃ CCH(OH)CH ₂ I (22.2 g., 59%)	163
C₃H₅OCl			
α -Epichlorohydrin	CH ₃ MgI	ClCH ₂ CH(OH)CH ₂ I (<i>ca.</i> quant.)	82
α -Epichlorohydrin	C ₂ H ₅ MgBr (0.5 equiv.)	ClCH ₂ (<i>n</i> -C ₃ H ₇)CHOH (80%)	32,73; <i>cf.</i> 60
α -Epichlorohydrin (92.5 g., 1 mole)	C ₂ H ₅ MgBr (109.0 g., 1 mole C ₂ H ₅ Br)	ClCH ₂ (<i>n</i> -C ₃ H ₇)CHOH (20–23 g., 16–19%); ClCH ₂ CH(OH)CH ₂ Br (<i>ca.</i> , 100 g.)	83,75
α -Epichlorohydrin (0.82–0.91 mole)	C ₂ H ₅ MgBr (1 equiv.)	ClCH ₂ (<i>n</i> -C ₃ H ₇)CHOH (4.5–13.0%); ClCH ₂ CH(OH)CH ₂ Br (41–61%); (CH ₂) ₂ CHOH (0.0–4.5 g.); C ₂ H ₄ ; C ₂ H ₆ , tar (0.0–8.6 g.)*	89
α -Epichlorohydrin (1.35 mole)	C ₂ H ₅ MgBr (0.9 mole)	ClCH ₂ (<i>n</i> -C ₃ H ₇)CHOH (35%); ClCH ₂ CH(OH)CH ₂ Br (78%)	89
α -Epichlorohydrin	C ₂ H ₅ MgBr [†]	(CH ₂) ₂ CHOH (6.0%) [‡]	125
α -Epichlorohydrin (1.66 mole) + MgBr ₂ (1.66 mole)	C ₂ H ₅ MgBr (5 moles) + FeCl ₃ (0.0015 mole)	(CH ₂) ₂ CHOH (31%); gas	125

* The results of three experiments, conducted under varying conditions, are summarized. Compare with reactions of ClCH₂CH(OMgBr)CH₂Br with C₂H₅MgBr, Table XVI-I (C₃H₅Br₂ClMgO).

[†] From pure sublimed magnesium.

[‡] Compare with the reaction of ClCH₂CH(OH)CH₂Br with C₂H₅MgBr, Table XVI-I (C₃H₅BrClO).

TABLE XVI-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₅OCl (<i>cont.</i>)			
α -Epichlorohydrin (1 mole) + MgBr ₂ (1 mole)	C ₂ H ₅ MgBr (3 moles) + FeCl ₃ (0.0014 mole)	(CH ₂) ₂ CHOH (43%); gas	125
α -Epichlorohydrin (1.1 mole)	(C ₂ H ₅) ₂ Mg (0.548 mole)	ClCH ₂ (<i>n</i> -C ₃ H ₇)CHOH (70–83%)	89
α -Epichlorohydrin (44 g.)	<i>n</i> -C ₃ H ₇ MgI (1 equiv.)	ClCH ₂ (<i>n</i> -C ₄ H ₉)CHOH* (2.5 g., 3.9%)	84
α -Epichlorohydrin (42 g.)	<i>i</i> -C ₃ H ₇ MgBr (1 equiv.)	No chlorohydrin isolated	84
α -Epichlorohydrin	<i>i</i> -C ₃ H ₇ MgI (1 equiv.)	No chlorohydrin isolated	84
α -Epichlorohydrin (46.2 g.)	<i>n</i> -C ₄ H ₉ MgCl (1 equiv.)	ClCH ₂ (<i>n</i> -C ₃ H ₁₁)CHOH (12.0 g., 16%)	84
α -Epichlorohydrin (38.8 g.)	<i>s</i> -C ₄ H ₉ MgCl (1 equiv.)	ClCH ₂ (<i>s</i> -C ₄ H ₉ CH ₂)CHOH* (3.8 g., 9%)	84
α -Epichlorohydrin (23.0 g.)	<i>t</i> -C ₄ H ₉ MgCl (1 equiv.)	No chlorohydrin isolated	84
α -Epichlorohydrin (39.8 g.)	<i>n</i> -C ₅ H ₁₁ MgCl (1 equiv.)	ClCH ₂ (<i>n</i> -C ₆ H ₁₃)CHOH* (12.0 g., 29.8%)	84
α -Epichlorohydrin (29.4 g.)	(C ₂ H ₅) ₂ CHMgCl (1 equiv.)	ClCH ₂ [(C ₂ H ₅) ₂ CHCH ₂]CHOH* (5.7 g., 10.9%)	84
α -Epichlorohydrin (25.9 g.)	C ₆ H ₅ MgBr (1 equiv.)	ClCH ₂ (C ₆ H ₅ CH ₂)CHOH (8.7 g., 18.2%)	84,161
α -Epichlorohydrin (46.2 g.)	C ₆ H ₅ MgBr (78.5 g. C ₆ H ₅ Br)	ClCH ₂ (C ₆ H ₅ CH ₂)CHOH (30.0 g.); ClCH ₂ CH(OH)CH ₂ Br	37,75,180
α -Epichlorohydrin (46 g.)	C ₆ H ₅ MgBr (78 g. C ₆ H ₅ Br)	CH ₃ (C ₆ H ₅)C=CHC ₆ H ₅ (10 g.); ClCH ₂ CH(OH)CH ₂ Br (23 g.)	128
α -Epichlorohydrin	C ₆ H ₅ MgI	ClCH ₂ (C ₆ H ₅)CHCH ₂ OH†	110
α -Epichlorohydrin (40.6 g.)	(CH ₂) ₅ CHMgCl (1 equiv.)	ClCH ₂ [(CH ₂) ₅ CHCH ₂]CHOH (11.9 g., 15.3%)	84
α -Epichlorohydrin	3-F ₃ CC ₆ H ₄ MgBr	3-F ₃ CC ₆ H ₄ CH ₂ CH(OH)CH ₂ Cl (70%)	191
α -Epichlorohydrin (62 g.)	C ₆ H ₅ CH ₂ MgCl (84 g. C ₇ H ₇ Cl)	ClCH ₂ (C ₆ H ₅ CH ₂ CH ₂)CHOH (70 g.); ClCH ₂ CH(OH)CH ₂ Br (28 g.)	37,180
α -Epichlorohydrin (31.0 g.)	C ₆ H ₅ CH ₂ MgCl (1 equiv.)	ClCH ₂ (C ₆ H ₅ CH ₂ CH ₂)CHOH* (19.7 g., 32.0%); tar (7.8 g.)	84

* Structure assumed.

† The structure assigned is undoubtedly erroneous; the general formula for the products claimed should be ClCH₂(RCH₂)CHOH rather than R(ClCH₂)CHCH₂OH.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₅OCl (<i>cont.</i>)			
α -Epichlorohydrin	2-CH ₃ OC ₆ H ₄ MgBr	ClCH ₂ (2-CH ₃ OC ₆ H ₄ CH ₂)CHOH (25–30%)	101
α -Epichlorohydrin (60 g.)	4-CH ₃ OC ₆ H ₄ MgBr (125 g. C ₇ H ₇ BrO)	ClCH ₂ (4-CH ₃ OC ₆ H ₄ CH ₂)CHOH (36 g.); ClCH ₂ CH(OH)CH ₂ Br	37,180,161
α -Epichlorohydrin (24.0 g.)	(CH ₂) ₅ CHCH ₂ MgCl (1 equiv.)	ClCH ₂ [(CH ₂) ₅ CHCH ₂ CH ₂]CHOH (14.7 g., 29.9%)	84
α -Epichlorohydrin	C ₆ H ₅ C \equiv CMgBr	ClCH ₂ (C ₆ H ₅ C \equiv CCH ₂)CHOH; ClCH ₂ CH(OH)CH ₂ Br; (C ₆ H ₅ C \equiv C—) ₂ ; C ₆ H ₅ C \equiv CH	74
α -Epichlorohydrin (28.0 g.)	C ₆ H ₅ CH ₂ CH ₂ MgCl (1 equiv.)	ClCH ₂ [C ₆ H ₅ (CH ₂) ₃]CHOH* (7.9 g., 12.8%)	84
α -Epichlorohydrin (5.7 g.)	(CH ₂) ₅ CHCH(CH ₃)MgCl (1 equiv.)	No chlorohydrin isolated	84
α -Epichlorohydrin (20.0 g.)	C ₆ H ₅ (CH ₂) ₃ MgCl	ClCH ₂ [C ₆ H ₅ (CH ₂) ₄]CHOH* (11.5 g., 25.0%)	84
α -Epichlorohydrin (180 g.)	1-C ₁₀ H ₇ MgBr (207 g. C ₁₀ H ₇ Br)	ClCH ₂ (1-C ₁₀ H ₇ CH ₂)CHOH (<i>ca.</i> 100 g.)	161
α -Epichlorohydrin	4-CH ₃ OC ₁₀ H ₆ -1-MgBr	ClCH ₂ (4-CH ₃ OC ₁₀ H ₆ -1-CH ₂)CHOH	161
C₃H₅OBr			
α -Epibromohydrin	C ₂ H ₅ MgBr	(BrCH ₂) ₂ CHOH	75
C₃H₆O			
Propylene oxide (0.40 mole)	(CH ₃) ₂ Mg (0.17 mole)	CH ₃ (C ₂ H ₅)CHOH (7.0 g., 28%)	51
Propylene oxide	C ₂ H ₅ MgCl (1.0 equiv.)	CH ₃ (<i>n</i> -C ₃ H ₇)CHOH (40%); CH ₃ CH(OH)CH ₂ Cl (35%)†	72
Propylene oxide	C ₂ H ₅ MgCl (1.0 equiv.)	CH ₃ (<i>n</i> -C ₃ H ₇)CHOH (42%); CH ₃ CH(OH)CH ₂ Cl (40%)†	72

* Structure assumed.

† Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; overnight standing.‡ Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; overnight standing; distillation of *ca.* half of Et₂O; addition of two volumes of C₆H₆; distillation to b.p. 75°; seven hours reflux with stirring; overnight standing.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₆O (<i>cont.</i>)			
Propylene oxide	C ₂ H ₅ MgCl (0.5 equiv.)	CH ₃ (<i>n</i> -C ₃ H ₇)CHOH (56%); CH ₃ CH(OH)CH ₂ Cl (73%)*	72
Propylene oxide	C ₂ H ₅ MgBr	CH ₃ (<i>n</i> -C ₃ H ₇)CHOH (60%)	60
Propylene oxide (45 g.)	C ₂ H ₅ MgBr (1.0 equiv.)	CH ₃ (<i>n</i> -C ₃ H ₇)CHOH (8 g., 11.7%); (C ₂ H ₅) ₂ CHOH	103
Propylene oxide	C ₂ H ₅ MgBr (1.0 equiv.)	CH ₃ (<i>n</i> -C ₃ H ₇)CHOH (13%); CH ₃ CH(OH)CH ₂ Br	69
Propylene oxide	C ₂ H ₅ MgBr (0.5 equiv.)	CH ₃ (<i>n</i> -C ₃ H ₇)CHOH (54%); CH ₃ CH(OH)CH ₂ Br (76%)	69
Propylene oxide (25.2 g.)	(C ₂ H ₅) ₂ Mg (0.47 equiv.)	CH ₃ (<i>n</i> -C ₃ H ₇)CHOH (9.0 g., 23%)	103
Propylene oxide	<i>n</i> -C ₃ H ₇ MgCl (1.0 equiv.)	CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (28%); CH ₃ CH(OH)CH ₂ Cl (50%)†	72
Propylene oxide	<i>n</i> -C ₃ H ₇ MgCl (1.0 equiv.)	CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (31%); CH ₃ CH(OH)CH ₂ Cl (35%)‡	72
Propylene oxide	<i>n</i> -C ₃ H ₇ MgCl (0.5 equiv.)	CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (63%); CH ₃ CH(OH)CH ₂ Cl (64%)*	72
Propylene oxide	<i>n</i> -C ₃ H ₇ MgBr (1.0 equiv.)	CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (4%); CH ₃ CH(OH)CH ₂ Br (69%)	69
Propylene oxide	<i>n</i> -C ₃ H ₇ MgBr (0.5 equiv.)	CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (51%); CH ₃ CH(OH)CH ₂ Br (74%)	69
(+)-Propylene oxide	<i>n</i> -C ₃ H ₇ MgBr	(-)-CH ₃ (<i>n</i> -C ₄ H ₉)CHOH	87
Propylene oxide	<i>i</i> -C ₃ H ₇ MgCl (1.0 equiv.)	CH ₃ (<i>i</i> -C ₄ H ₉)CHOH (23%); CH ₃ CH(OH)CH ₂ Cl (55%)†	72

* Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; several days standing (to negative Michler's ketone test).

† Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; overnight standing.

‡ Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; overnight standing; distillation of ca. half of Et₂O; addition of two volumes of C₆H₆; distillation to b.p. 75°; seven hours reflux with stirring; overnight standing.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₆O (<i>cont.</i>)			
Propylene oxide	<i>i</i> -C ₃ H ₇ MgCl (1.0 equiv.)	CH ₃ (<i>i</i> -C ₄ H ₉)CHOH (30%); CH ₃ CH(OH)CH ₂ Cl (53%)*	72
Propylene oxide	<i>i</i> -C ₃ H ₇ MgCl (0.5 equiv.)	CH ₃ (<i>i</i> -C ₄ H ₉)CHOH (46%); CH ₃ CH(OH)CH ₂ Cl (81%)†	72
Propylene oxide	<i>i</i> -C ₃ H ₇ MgBr (1.0 equiv.)	CH ₃ (<i>i</i> -C ₄ H ₉)CHOH (7%); CH ₃ CH(OH)CH ₂ Br (50%)	69
Propylene oxide	<i>i</i> -C ₃ H ₇ MgBr (0.5 equiv.)	CH ₃ (<i>i</i> -C ₄ H ₉)CHOH (38%); CH ₃ CH(OH)CH ₂ Cl (76%)	69
(+)-Propylene oxide	<i>i</i> -C ₃ H ₇ MgBr	(-)-CH ₃ (<i>i</i> -C ₄ H ₉)CHOH	88
Propylene oxide (116 g., 2 moles)	2-Thienyl-MgBr (163 g., 1 mole C ₄ H ₃ BrS)	1-(2-Thienyl)-2-propanol (84.5 g., 60%)	193
Propylene oxide (30 g.)	Pyrryl-MgBr (34 g. C ₄ H ₅ N)	1- α -Pyrryl-2-propanol	62
Propylene oxide	<i>n</i> -C ₄ H ₉ MgCl (1.0 equiv.)	CH ₃ (<i>n</i> -C ₅ H ₁₁)CHOH (41%); CH ₃ CH(OH)CH ₂ Cl (52%)‡	72
Propylene oxide	<i>n</i> -C ₄ H ₉ MgCl (1.0 equiv.)	CH ₃ (<i>n</i> -C ₅ H ₁₁)CHOH (58%); CH ₃ CH(OH)CH ₂ Cl (28%)*	72
Propylene oxide	<i>n</i> -C ₄ H ₉ MgCl (0.5 equiv.)	CH ₃ (<i>n</i> -C ₅ H ₁₁)CHOH (59%); CH ₃ CH(OH)CH ₂ Cl (77%)†	72
Propylene oxide (12 g.)	<i>n</i> -C ₄ H ₉ MgBr (28 g. C ₄ H ₉ Br)	CH ₃ (<i>n</i> -C ₅ H ₁₁)CHOH (30%);	91
Propylene oxide	<i>n</i> -C ₄ H ₉ MgBr (1.0 equiv.)	CH ₃ (<i>n</i> -C ₅ H ₁₁)CHOH (5%); CH ₃ CH(OH)CH ₂ Br (67%)	69
Propylene oxide	<i>n</i> -C ₄ H ₉ MgBr (0.5 equiv.)	CH ₃ (<i>n</i> -C ₅ H ₁₁)CHOH (56%); CH ₃ CH(OH)CH ₂ Br (70%)	69

* Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; overnight standing; distillation of *ca.* half of Et₂O; addition of two volumes of C₆H₆; distillation to b.p. 75°; seven hours reflux with stirring; overnight standing.

† Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; several days standing (to negative Michler's ketone test).

‡ Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; overnight standing.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₆O (<i>cont.</i>)			
Propylene oxide	<i>i</i> -C ₄ H ₉ MgCl (1.0 equiv.)	CH ₃ (<i>i</i> -C ₅ H ₁₁)CHOH (19%); CH ₃ CH(OH)CH ₂ Cl (58%)*	72
Propylene oxide	<i>i</i> -C ₄ H ₉ MgCl (1.0 equiv.)	CH ₃ (<i>i</i> -C ₅ H ₁₁)CHOH (40%); CH ₃ CH(OH)CH ₂ Cl (19%)†	72
Propylene oxide	<i>i</i> -C ₄ H ₉ MgCl (0.5 equiv.)	CH ₃ (<i>i</i> -C ₅ H ₁₁)CHOH (62%); CH ₃ CH(OH)CH ₂ Cl (73%)‡	72
Propylene oxide (12 g.)	<i>i</i> -C ₄ H ₉ MgBr (28 g. C ₄ H ₉ Br)	CH ₃ (<i>i</i> -C ₅ H ₁₁)CHOH (20%)	91
Propylene oxide	<i>i</i> -C ₄ H ₉ MgBr (1.0 equiv.)	CH ₃ (<i>i</i> -C ₅ H ₁₁)CHOH (4%); CH ₃ CH(OH)CH ₂ Br (64%)	69
Propylene oxide	<i>i</i> -C ₄ H ₉ MgBr (0.5 equiv.)	CH ₃ (<i>i</i> -C ₅ H ₁₁)CHOH (15%); CH ₃ CH(OH)CH ₂ Br (28%)	69
Propylene oxide	<i>s</i> -C ₄ H ₉ MgCl (1.0 equiv.)	CH ₃ (<i>s</i> -C ₄ H ₉ CH ₂)CHOH (10%); CH ₃ CH(OH)CH ₂ Cl (54%)*	72
Propylene oxide	<i>s</i> -C ₄ H ₉ MgCl (1.0 equiv.)	CH ₃ (<i>s</i> -C ₄ H ₉ CH ₂)CHOH (16%); CH ₃ CH(OH)CH ₂ Cl (24%)†	72
Propylene oxide	<i>s</i> -C ₄ H ₉ MgCl (0.5 equiv.)	CH ₃ (<i>s</i> -C ₄ H ₉ CH ₂)CHOH (30%); CH ₃ CH(OH)CH ₂ Cl (69%)‡	72
Propylene oxide	<i>s</i> -C ₄ H ₉ MgBr (1.0 equiv.)	CH ₃ (<i>s</i> -C ₄ H ₉ CH ₂)CHOH (4%); CH ₃ CH(OH)CH ₂ Br (62%)	69
Propylene oxide	<i>s</i> -C ₄ H ₉ MgBr (0.5 equiv.)	CH ₃ (<i>s</i> -C ₄ H ₉ CH ₂)CHOH (31%); CH ₃ CH(OH)CH ₂ Br (62%)	69
Propylene oxide (220 g.)	<i>t</i> -C ₄ H ₉ MgCl (150 g. Mg)	C ₂ H ₅ (<i>t</i> -C ₄ H ₉)CHOH (11%)	126

* Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; overnight standing.

† Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; overnight standing; distillation of *ca.* half of Et₂O; addition of two volumes of C₆H₆; distillation to b.p. 75°; seven hours reflux with stirring; overnight standing.

‡ Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; several days standing (to negative Michler's ketone test).

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₆O (cont.)			
Propylene oxide	<i>t</i> -C ₄ H ₉ MgCl (1.0 equiv.)	CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (0%); CH ₃ CH(OH)CH ₂ Cl (65%)*	72
Propylene oxide	<i>t</i> -C ₄ H ₉ MgCl (1.0 equiv.)	CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (25%); CH ₃ CH(OH)CH ₂ Cl (3%)†	72
Propylene oxide	<i>t</i> -C ₄ H ₉ MgCl (0.5 equiv.)	CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (15%); CH ₃ CH(OH)CH ₂ Cl (61%)‡	72
Propylene oxide	<i>t</i> -C ₄ H ₉ MgBr (1.0 equiv.)	CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (4%); CH ₃ CH(OH)CH ₂ Br (62%)	69
Propylene oxide	<i>t</i> -C ₄ H ₉ MgBr (0.5 equiv.)	CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (15%); CH ₃ CH(OH)CH ₂ Br (52%)	69
Propylene oxide (180 g.)	C ₆ H ₅ MgBr (471 g. C ₆ H ₅ Br)	CH ₃ (C ₆ H ₅ CH ₂)CHOH (244 g., 60%)	98
Propylene oxide	C ₆ H ₅ MgBr (1.0 equiv.)	CH ₃ (C ₆ H ₅ CH ₂)CHOH (47%); CH ₃ CH(OH)CH ₂ Br (39%)	69
Propylene oxide	C ₆ H ₅ MgBr (0.5 equiv.)	CH ₃ (C ₆ H ₅ CH ₂)CHOH (67%); CH ₃ CH(OH)CH ₂ Br (74%)	69
(+)-Propylene oxide	C ₆ H ₅ MgBr	(-)-CH ₃ (C ₆ H ₅ CH ₂)CHOH	87
Propylene oxide	3-F ₃ CC ₆ H ₄ MgBr	CH ₃ (3-F ₃ CC ₆ H ₄ CH ₂)CHOH + 3- F ₃ CC ₆ H ₄ CH(CH ₃)CH ₂ OH (aggregating 43%)	191
Propylene oxide	2-CH ₃ C ₆ H ₄ MgBr	CH ₃ (2-CH ₃ C ₆ H ₄ CH ₂)CHOH (55%)	100
Propylene oxide	3-CH ₃ C ₆ H ₄ MgBr	CH ₃ (3-CH ₃ C ₆ H ₄ CH ₂)CHOH	116
Propylene oxide (88.0 g., 1.5 mole)	4-CH ₃ C ₆ H ₄ MgBr (256.5 g., 1.5 mole C ₇ H ₇ Br)	CH ₃ (4-CH ₃ C ₆ H ₄ CH ₂)CHOH (87.1 g.)	116

* Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; overnight standing.

† Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; overnight standing; distillation of *ca.* half of Et₂O; addition of two volumes of C₆H₆; distillation to b.p. 75°; seven hours reflux with stirring; overnight standing.

‡ Dropwise addition of Et₂O-oxide solution to stirred Grignard reagent solution; one hour stirring; several days standing (to negative Michler's ketone test).

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₆O (<i>cont.</i>)			
Propylene oxide	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr (1 equiv.)	CH ₃ [2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂]CHOH (58%); CH ₃ CH(OH)CH ₂ Br (35%)	69
C₄H₆O			
3,4-Epoxy-1-butene	CH ₃ MgBr	C ₂ H ₅ CH=CHCH ₂ OH; CH ₃ (H ₂ C=CH)CHCH ₂ OH	181
3,4-Epoxy-1-butene	CH ₃ MgI	C ₂ H ₅ CH=CHCH ₂ OH (35.7%)	115
3,4-Epoxy-1-butene (60.0 g., 0.855 mole)	C ₂ H ₅ MgBr (0.859 mole)	C ₂ H ₅ (H ₂ C=CHCH ₂)CHOH (16.1 g., 0.161 mole, 18.9%); C ₂ H ₅ (H ₂ C=CH)CHCH ₂ OH (20.1 g., 0.201 mole, 23.5%); <i>n</i> -C ₃ H ₇ CH=CHCH ₂ OH (26.8 g., 0.268 mole, 31.4%)	38
3,4-Epoxy-1-butene (106.0 g., 1.52 mole)	(C ₂ H ₅) ₂ Mg (0.76 mole)	C ₂ H ₅ (H ₂ C=CH)CHCH ₂ OH (41.2 g., 53.4%); <i>n</i> -C ₃ H ₇ CH=CHCH ₂ OH (13.1 g., 16.9%)	38
3,4-Epoxy-1-butene (52 g., 0.72 mole)	2-Thienyl-MgBr (135 g., 0.83 mole C ₄ H ₃ BrS)	(α -C ₄ H ₃ S)CH ₂ CH=CHCH ₂ OH (40 g., 26%)	42
3,4-Epoxy-1-butene	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ CH=CHCH ₂ OH (38.0%)	115
3,4-Epoxy-1-butene	(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CHCH ₂ CH=CHCH ₂ OH (34.0%)	115
3,4-Epoxy-1-butene	2-C ₂ H ₅ OC ₆ H ₄ MgBr	2-C ₂ H ₅ OC ₆ H ₄ CH ₂ CH=CHCH ₂ OH (14.7%)	115
3,4-Epoxy-1-butene	1-C ₁₀ H ₇ MgBr	1-C ₁₀ H ₇ CH ₂ CH=CHCH ₂ OH (30.2%)	115; <i>cf.</i> 41
3,4-Epoxy-1-butene (17.5 g., 0.25 mole)	1-C ₁₀ H ₇ MgBr (51.8 g., 0.25 mole C ₁₀ H ₇ Br)	H ₂ C=CH(1-C ₁₀ H ₇ CH ₂)CHOH (27.2-28.6 g., 0.137-0.145 mole, 55-58%)	41
C₄H₈O			
(+)- α -Butylene oxide	<i>n</i> -C ₃ H ₇ MgBr	(-)-C ₃ H ₇ (<i>n</i> -C ₄ H ₉)CHOH	88
(+)- α -Butylene oxide	<i>i</i> -C ₃ H ₇ MgBr	(-)-C ₃ H ₇ (<i>i</i> -C ₄ H ₉)CHOH	88
β -Butylene oxide	CH ₃ MgBr (1.0 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (7%); C ₂ H ₅ (CH ₃) ₂ COH (44%)	27,59

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₈O (<i>cont.</i>)			
β -Butylene oxide (0.20 mole)	(CH ₃) ₂ Mg (0.105 mole)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (6.1 g., 35%)	27
β -Butylene oxide	C ₂ H ₅ MgCl (1.0 equiv.)	CH ₃ (<i>s</i> -C ₄ H ₉)CHOH (27%); CH ₃ (C ₂ H ₅) ₂ COH (30%)	27
β -Butylene oxide	C ₂ H ₅ MgBr (1.0 equiv.)	CH ₃ (<i>s</i> -C ₄ H ₉)CHOH (2%); CH ₃ (C ₂ H ₅) ₂ COH (31%)	27
β -Butylene oxide	C ₂ H ₅ MgI (1.0 equiv.)	CH ₃ (<i>s</i> -C ₄ H ₉)CHOH (trace); CH ₃ (C ₂ H ₅) ₂ COH (27%)	27
β -Butylene oxide (0.62 mole)	(C ₂ H ₅) ₂ Mg (0.62 mole)	CH ₃ (<i>s</i> -C ₄ H ₉)CHOH (50 g., 79%)	27
<i>cis</i> - β -Butylene oxide (14.0 g.)	C ₂ H ₅ MgBr (1.0 equiv.)	CH ₃ (C ₂ H ₅) ₂ COH (3.5 g., 17.5%)	103
<i>cis</i> - β -Butylene oxide (19.0 g.)	(C ₂ H ₅) ₂ Mg (0.4 equiv.)	CH ₃ (<i>s</i> -C ₄ H ₉)CHOH (16.5 g., 61.0%)	103
<i>trans</i> - β -Butylene oxide (15.0 g.)	C ₂ H ₅ MgBr (1.0 equiv.)	CH ₃ (C ₂ H ₅) ₂ COH (10.5 g., 49.0%)	103
<i>trans</i> - β -Butylene oxide (21.0 g.)	(C ₂ H ₅) ₂ Mg (0.4 equiv.)	CH ₃ (<i>s</i> -C ₄ H ₉)CHOH (6.5 g., 21.8%)	103
Isobutylene oxide	CH ₃ MgBr	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (80.0%)	57,58
Isobutylene oxide	CH ₃ MgBr (2.0 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇)CHOH (40.8%); BrCH ₂ C(CH ₃) ₂ OH (40.2%)	70
Isobutylene oxide	(CH ₃) ₂ Mg (1.0 equiv.)	C ₂ H ₅ (CH ₃) ₂ COH	70
Isobutylene oxide (135 g.)	C ₂ H ₅ MgBr (1.0 equiv.)	C ₂ H ₅ (<i>i</i> -C ₃ H ₇)CHOH (39 g., 21%)	103
Isobutylene oxide	C ₂ H ₅ MgBr (0.5 equiv.)	C ₂ H ₅ (<i>i</i> -C ₃ H ₇)CHOH (13.2%); <i>n</i> - C ₃ H ₇ (CH ₃) ₂ COH (17.9%); (C ₄ H ₈ O) ₃ (14.0%); BrCH ₂ C(CH ₃) ₂ OH (51.2%)	70
Isobutylene oxide	C ₂ H ₅ MgBr (1.0 equiv.)	C ₂ H ₅ (<i>i</i> -C ₃ H ₇)CHOH (42.2%); BrCH ₂ C(CH ₃) ₂ OH (28.3%)	70
Isobutylene oxide	C ₂ H ₅ MgBr (2.0 equiv.)	C ₂ H ₅ (<i>i</i> -C ₃ H ₇)CHOH (51.4%); BrCH ₂ C(CH ₃) ₂ OH (40.4%)	70
Isobutylene oxide (29.0 g.)	(C ₂ H ₅) ₂ Mg (0.37 equiv.)	<i>n</i> -C ₃ H ₇ (CH ₃) ₂ COH (11.3 g., 27.5%)	103
Isobutylene oxide	(C ₂ H ₅) ₂ Mg (1.0 equiv.)	<i>n</i> -C ₃ H ₇ (CH ₃) ₂ COH (35.0%)	70
Isobutylene oxide	<i>n</i> -C ₃ H ₇ MgBr (0.5 equiv.)	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇)CHOH (12.8%); <i>n</i> -C ₄ H ₉ (CH ₃) ₂ COH (15.2%); (C ₄ H ₈ O) ₃ (28.0%); BrCH ₂ C(CH ₃) ₂ OH (57.2%)	70

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₈O (<i>cont.</i>)			
Isobutylene oxide	<i>n</i> -C ₃ H ₇ MgBr (1.0 equiv.)	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇)CHOH (39.4%); BrCH ₂ C(CH ₃) ₂ OH (30.5%)	70
Isobutylene oxide	<i>n</i> -C ₃ H ₇ MgBr (2.0 equiv.)	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇)CHOH (44.5%); BrCH ₂ C(CH ₃) ₂ OH (23.0%)	70
Isobutylene oxide	(<i>n</i> -C ₃ H ₇) ₂ Mg (1.0 equiv.)	<i>n</i> -C ₄ H ₉ (CH ₃) ₂ COH (25.5%)	70
Isobutylene oxide	<i>i</i> -C ₃ H ₇ MgBr (2.0 equiv.)	(<i>i</i> -C ₃ H ₇) ₂ CHOH (21.5%); BrCH ₂ C(CH ₃) ₂ OH (60.0%)	70
Isobutylene oxide	<i>n</i> -C ₄ H ₉ MgBr (2.0 equiv.)	<i>n</i> -C ₄ H ₉ (<i>i</i> -C ₃ H ₇)CHOH (20.1%); BrCH ₂ C(CH ₃) ₂ OH (41.0%)	70
Isobutylene oxide	(<i>n</i> -C ₄ H ₉) ₂ Mg	<i>n</i> -C ₅ H ₁₁ (CH ₃) ₂ COH (11.5%)	70
Isobutylene oxide	<i>t</i> -C ₄ H ₉ MgBr (2.0 equiv.)	<i>i</i> -C ₃ H ₇ (<i>t</i> -C ₄ H ₉)CHOH (0.0%); BrCH ₂ (CH ₃) ₂ OH (56.0%)	70
Isobutylene oxide	(<i>t</i> -C ₄ H ₉) ₂ Mg	<i>t</i> -C ₄ H ₉ CH ₂ (CH ₃) ₂ COH (6.0%)	70
C₄H₈O₂			
1,2-Epoxy-3-methoxypropane	C ₆ H ₅ MgBr	CH ₃ OCH ₂ (C ₆ H ₅ CH ₂)CHOH; BrCH ₂ (CH ₃ OCH) ₂ CHOH	109
C₅H₈O			
Cyclopentene oxide	CH ₃ MgI (2.0 equiv.)	<i>cis</i> -2-Methylcyclopentanol ("good yield")	46
Cyclopentene oxide (3.9 g.)	CH ₃ MgI (2.0 equiv.)	2-Iodocyclopentanol	141
C₅H₈OBr			
1-Bromo-2,3-epoxypentane (33 g.)	C ₂ H ₅ MgBr (30 g. C ₂ H ₅ Br)	BrCH ₂ (C ₂ H ₅ CHBr)CHOH (20 g.)	30,29
1-Bromo-2,3-epoxypentane (33 g.)	C ₆ H ₅ MgBr (38 g. C ₆ H ₅ Br)	BrCH ₂ (C ₂ H ₅ CHBr)CHOH (14 g.); unidenti- fied products (12 g.)	30,29

TABLE XIV-I (Continued)

<u>Epoxyde</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₁₀O			
2,3-Epoxy-pentane	C ₂ H ₅ MgBr	CH ₃ [(C ₂ H ₅) ₂ CH]CHOH	36
1,2-Epoxy-2-methylbutane	C ₂ H ₅ MgBr	C ₂ H ₅ (<i>s</i> -C ₄ H ₉)CHOH	36
1,2-Epoxy-3-methylbutane (17 g.)	C ₂ H ₅ MgBr (22 g. C ₂ H ₅ Br)	<i>n</i> -C ₃ H ₇ (<i>i</i> -C ₃ H ₇)CHOH (63%)	174
1,2-Epoxy-3-methylbutane	<i>n</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (<i>n</i> -C ₄ H ₉)CHOH (38%)	174
1,2-Epoxy-3-methylbutane	<i>i</i> -C ₃ H ₇ MgBr	<i>i</i> -C ₃ H ₇ (<i>i</i> -C ₄ H ₉)CHOH (41%)	174
2,3-Epoxy-2-methylbutane	CH ₃ MgBr	<i>i</i> -C ₃ H ₇ (CH ₃) ₂ COH	56,61
2,3-Epoxy-2-methylbutane (40 g.)	C ₂ H ₅ MgBr (1.0 equiv.)	CH ₃ (C ₂ H ₅)(<i>i</i> -C ₃ H ₇)COH (27 g., 50%)	103
2,3-Epoxy-2-methylbutane (25.8 g.)	(C ₂ H ₅) ₂ Mg (0.4 equiv.)	<i>s</i> -C ₄ H ₉ (CH ₃) ₂ COH (7.0 g., 21%)	103
C₆H₈O			
3,4-Epoxy-cyclohexene	C ₂ H ₅ MgBr	2-Cyclopentene-1-carboxaldehyde; 3-cyclohexen-1-one	132
4,5-Epoxy-cyclohexene	C ₂ H ₅ MgBr	3-Cyclopentene-1-carboxaldehyde; 3-cyclohexen-1-one	132
C₈H₁₆O			
1-Methylcyclopentene oxide	CH ₃ MgI	1,2-Dimethylcyclopentanol* (40%)	151
Cyclohexene oxide	CH ₃ MgBr	(CH ₂) ₄ CHCH ₂ OH; CH ₃ COCH(CH ₂) ₄ (20-25%)	10
Cyclohexene oxide (26 g.)	CH ₃ MgI (80 g. CH ₃ I)	(CH ₂) ₄ CHCH(CH ₃)OH† (63%)	48,43
Cyclohexene oxide	(CH ₃) ₂ Mg	<i>trans</i> -2-Methylcyclohexanol	7
Cyclohexene oxide	C ₂ H ₅ MgBr	(CH ₂) ₄ CHCH ₂ OH and C ₂ H ₅ COCH(CH ₂) ₄ (aggregating 55%)	10; cf. 142

* This product is said to be stereoisomeric with that obtained by van Rysselberge, *Bull. acad. roy. Belg., Classe sci.*, [5], 12, 171-92 (1926), through the reaction of 2-methylcyclopentanone with CH₃MgI.

† Erroneously reported by Godchot and Bedos (48,43) as *cis*-2-methylcyclohexanol; cf. Vavon and Mitchovitch (137); Godchot, Bedos, and Cauquil (166).

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₀O (<i>cont.</i>)			
Cyclohexene oxide (18.5 g.)	(C ₂ H ₅) ₂ Mg (180 ml., 1.04 <i>N</i>)	<i>trans</i> -2-Methylcyclohexanol (10.0 g., 42%)	7
Cyclohexene oxide (24.5 g., 0.25 mole)	H ₂ C=CHCH ₂ MgBr (0.75 mole C ₃ H ₅ Br)	2-Allylcyclohexanol* (22.5 g., 64%); 2-bromocyclohexanol (?)	172
Cyclohexene oxide	C ₆ H ₅ MgBr	2-Bromocyclohexanol (chief product); 2-phenylcyclohexanol	8,142,143; <i>cf.</i> 24
Cyclohexene oxide	C ₆ H ₅ MgBr	(CH ₂) ₄ CH(C ₆ H ₅)CHOH	24
Cyclohexene oxide	(CH ₂) ₅ CHMgCl	(CH ₂) ₄ CH[(CH ₂) ₅ CH]CHOH	136; <i>cf.</i> 9, 144
Cyclohexene oxide (35.0 g.)	C ₆ H ₅ CH ₂ MgCl (47.5 ml. C ₇ H ₇ Cl)	2-Benzylcyclohexanol† (34.0 g., 50%); stereoisomeric 2-chlorocyclohexanols (10.0 g.)	24
Cyclohexene oxide (19.8 g.)	C ₆ H ₅ CH ₂ CH ₂ MgBr (74.0 g. C ₆ H ₅ Br)	(CH ₂) ₄ CH(C ₆ H ₅ CH ₂ CH ₂)CHOH† (37.3 g., 91.5%)	39
C₆H₁₀O₂			
1,2,5,6-Diepoxyhexane (4.4 g.)	CH ₃ MgI (2.4 equiv. CH ₃ I)	1,6-Diiodo-2,5-dihydroxyhexane, m. 116–117° (0.4 g.); stereoisomer, m. 94–95° (4.8 g.)	110
C₆H₁₂O			
2,3-Epoxy-2,3-dimethylbutane (50 g.)	C ₂ H ₅ MgBr (1.0 equiv.)	CH ₃ (C ₂ H ₅)(<i>t</i> -C ₄ H ₉)COH (25 g., 38%)	103

* The identity of the product was established by hydrogenation to 2-propylcyclohexanol, followed by oxidation to 2-propylcyclohexanone, which was compared with an authentic specimen directly and through the oximes, semicarbazones, and 2,4-dinitrophenylhydrazones.

† The identity of the product was established by oxidation to the ketone and comparison of the semicarbazone with that of an authentic specimen (from α -benzylpimelic acid).

‡ Erroneously reported by Fulton and Robinson (39) as 2-phenethylcyclohexanol; *cf.*, however, Cook *et al.* (24) and Robinson (112).

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₂O (<i>cont.</i>)			
2,3-Epoxy-2,3-dimethylbutane (20 g.)	(C ₂ H ₅) ₂ Mg (0.4 equiv.)	C ₂ H ₅ (CH ₃) ₂ C(CH ₃) ₂ COH (9 g., 34.6%)	103
C₇H₁₂O			
1,2-Epoxy-4-methylcyclohexane (26 g.)	CH ₃ MgI (80 g. CH ₃ I)	"cis"-2,5-Dimethoxycyclohexanol, * al- lophanate m. 157-158° (64%)	49,44
1,2-Epoxy-4-methylcyclohexane	<i>i</i> -C ₃ H ₇ MgBr	Menthol, * allophanate m. 177°	146,145
Cycloheptene oxide	CH ₃ MgI	1-Methylcycloheptanol†	47
C₈H₈O			
Styrene oxide	CH ₃ MgBr	CH ₃ (C ₆ H ₅ CH ₂)CHOH	131; <i>cf.</i> 36
Styrene oxide	CH ₃ MgI (1 equiv.)	CH ₃ (C ₆ H ₅ CH ₂)CHOH (51-53%)	51
Styrene oxide (0.25 mole)	(CH ₃) ₂ Mg (0.13 mole)	CH ₃ (C ₆ H ₅)CHCH ₂ OH (60%)	51
Styrene oxide	C ₂ H ₅ MgBr	C ₂ H ₅ (C ₆ H ₅ CH ₂)CHOH	131
Styrene oxide	C ₆ H ₅ MgBr (1 or 2 equiv.)	(C ₆ H ₅) ₂ CHCH ₂ OH‡	81
Styrene oxide	C ₆ H ₅ MgBr	C ₆ H ₅ (C ₆ H ₅ CH ₂)CHOH§	81
Styrene oxide	4-CH ₃ OC ₆ H ₄ MgBr	C ₆ H ₄ (4-CH ₃ OC ₆ H ₄)CHCH ₂ OH; C ₆ H ₄ (4-CH ₃ OC ₆ H ₄)C=CH ₂ ‡	81
Styrene oxide	4-CH ₃ OC ₆ H ₄ MgBr	4-CH ₃ OC ₆ H ₄ CH=CHC ₆ H ₅ §	81
C₉H₁₀O			
α -Methylstyrene oxide (25.0 g.)	<i>t</i> -C ₄ H ₉ MgCl (20.0 g. C ₄ H ₉ Cl)	<i>t</i> -C ₄ H ₉ [CH ₃ (C ₆ H ₅)CH]CHOH (10.5 g.); (<i>t</i> -C ₄ H ₉ —) ₂ (14.0 g.)	80

* It is altogether possible that the constitutional assignment is in error, and that the product is in fact a cyclopentylcarbinol.

† Gaylord and Becker, *Chem. Revs.*, 49, 488/ (1951), question the constitution assigned to this product. To say the least, the identification seems inadequate.

‡ Slow addition of oxide to stirred Grignard reagent solution; one hour reflux.

§ Slow addition of Grignard reagent solution to stirred, ice-cooled Et₂O-oxide solution; one hour reflux.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₀O (<i>cont.</i>)			
α-Methylstyrene oxide	C ₆ H ₅ MgBr	C ₆ H ₅ [CH ₃ (C ₆ H ₅)CH]CHOH	130
C₉H₁₀O₂			
Phenylglycide* (14.5 g.)	C ₆ H ₅ MgBr (16.0 g. C ₆ H ₅ Br)	C ₆ H ₅ CH ₂ (C ₆ H ₅ OCH ₂)CHOH (16.5 g., 75%)	15
C₉H₁₄O₄			
3,4-Isopropylidene-1,2,5,6-dianhydromannitol (3.7 g.)	CH ₃ MgI (3 ml., 2.4 equiv. CH ₃ I)	1,6-Diiodo-3,4-isopropylidene-1,6-dideoxymannitol (4.9 g., 54%)	110
C₉H₁₆O₄			
4,6-Dimethyl-α-methyl-2,3-anhydroalloside (14.5 g.)	CH ₃ MgI (12.7 g. CH ₃ I)	4,6-Dimethyl-α-methyl-3-iodo-3-deoxyglucoside (1.38 g., 5.8%); (after acetylation of residue): 3-acetyl-4,6-dimethyl-α-methyl-2-iodo-2-deoxyglucoside; 2-acetyl-4,6-dimethyl-α-methyl-3-deoxyglucoside (?) (2.45 g., 15.9%)	176
C₁₀H₁₂O			
1-Phenyl-2-methyl-1,2-epoxypropane	C ₂ H ₅ MgBr	C ₆ H ₅ [C ₂ H ₅ (CH ₃) ₂ C]CHOH; C ₂ H ₅ (C ₆ H ₅)CHC(CH ₃) ₂ OH	105
C₁₀H₁₂O₂			
1-Methoxy-1-phenyl-1,2-epoxypropane	CH ₃ MgI	CH ₃ (CH ₃ O)(C ₆ H ₅)CCH(OH)CH ₃ (85%)	190
1-Methoxy-1-phenyl-1,2-epoxypropane	C ₆ H ₅ MgBr	CH ₃ O(C ₆ H ₅) ₂ CCH(OH)CH ₃ (88%)	190,192

* 1-Phenyl-3-hydroxy-1,2-epoxypropane.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₆O			
α -Pinene oxide* (35 g.)	CH ₃ MgI (36 g. CH ₃ I)	α -2,2,3-Tetramethyl- Δ^3 -cyclopentene-ethanol (29 g.)	111,1; <i>c/f.</i> 106
α -Pinene oxide*	C ₂ H ₅ MgX (1.0 equiv.)	α -Ethyl-2,2,3-trimethyl- Δ^3 -cyclopentene-ethanol (<i>ca.</i> 70%)	111; <i>c/f.</i> 106
α -Pinene oxide*	<i>n</i> -C ₃ H ₇ MgX (1.0 equiv.)	α - <i>n</i> -Propyl-2,2,3-trimethyl- Δ^3 -cyclopentene $\ddot{\text{e}}$ thanol (<i>ca.</i> 70%)	111; <i>c/f.</i> 106
α -Pinene oxide*	<i>n</i> -C ₄ H ₉ MgX (1.0 equiv.)	α - <i>n</i> -Butyl-2,2,3-trimethyl- Δ^3 -cyclopentene $\ddot{\text{e}}$ thanol (<i>ca.</i> 70%)	111; <i>c/f.</i> 106
α -Pinene oxide*	<i>i</i> -C ₄ H ₉ MgX (1.0 equiv.)	α -Isobutyl-2,2,3-trimethyl- Δ^3 -cyclopentene $\ddot{\text{e}}$ thanol (<i>ca.</i> 70%)	111,1; <i>c/f.</i> 106
α -Pinene oxide*	C ₆ H ₅ MgBr (1.0 equiv.)	α -Phenyl-2,2,3-trimethyl- Δ^3 -cyclopentene-ethanol (<i>ca.</i> 70%)	111,1; <i>c/f.</i> 106
β -Pinene oxide†	RMgX	RH; "a monocyclic primary alcohol"†	179
C₁₁H₁₄O			
1-(1-Cyclohexenyl)-3-methyl-3,4-epoxy-1-butyne (8.1 g., 0.05 mole)	C ₂ H ₅ MgBr (0.075 mole)	4-Methyl-9-(1-cyclohexenyl)-5-hexyn-3-ol (6.0 g., 40%)	123
1-(1-Cyclohexenyl)-3-methyl-3,4-epoxy-1-butyne (48.0 g., 0.3 mole)	CH ₃ OCH ₂ CH=C(CH ₃)C \equiv CMgBr (0.3 mole)	1-(1-Cyclohexenyl)-3,7-dimethyl-9-methoxy-7-nonen-1,5-diyn-4-ol (7.7 g., 10%)	123
C₁₄H₁₂O			
Stilbene oxide (8.0 g.)	CH ₃ MgBr (8.0 g. CH ₃ Br)	α -C ₆ H ₅ [CH ₃ (C ₆ H ₅)CH]CHOH (<i>ca.</i> 5%); <i>trans</i> -(C ₆ H ₅ CH=) ₂	170,79

* 2,3-Epoxy-2,6,6-trimethylbicyclo[3.1.1]heptane.

† 2-Methylene-6,6-dimethylbicyclo[3.1.1]heptane oxide.

‡ According to Gaylord and Becker, *Chem. Revs.*, 49, 497 (1950), this product is probably a derivative of dihydromyrtanal.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₁₂O (<i>cont.</i>)			
Stilbene oxide	CH ₃ MgI	Complex mixture	170
Stilbene oxide	C ₂ H ₅ MgBr	β -C ₆ H ₅ [C ₂ H ₅ (C ₆ H ₅)CH]CHOH, * m. 82° (25%)	170,79
Stilbene oxide (8.0 g.)	C ₆ H ₅ CH ₂ MgCl	β -C ₆ H ₅ [C ₆ H ₅ (C ₆ H ₅ CH ₂)CH]CHOH, m. 87° (8.0 g., 50%); <i>trans</i> -(C ₆ H ₅ CH=) ₂ (3.0 g.)	170,79
Isostilbene oxide	CH ₃ MgBr	α -C ₆ H ₅ [CH ₃ (C ₆ H ₅)CH]CHOH; <i>trans</i> - (C ₆ H ₅ CH=) ₂	170
Isostilbene oxide	CH ₃ MgI	<i>trans</i> -(C ₆ H ₅ CH=) ₂ ; unidentified products	170
Isostilbene oxide	C ₂ H ₅ MgBr	α -C ₆ H ₅ [C ₂ H ₅ (C ₆ H ₅)CH]CHOH†	170
Isostilbene oxide (5.0 g.)	C ₆ H ₅ CH ₂ MgCl	α -C ₆ H ₅ [C ₆ H ₅ (C ₆ H ₅ CH ₂)CH]CHOH, m. 92° (3.5 g., 50%)	170,79
C₁₄H₁₆O₄			
4,6-Benzylidene- α -methyl-2,3-anhydroalloside (7.0 g.)	CH ₃ MgI (5.0 g. CH ₃ I)	4,6-Benzylidene- α -methyl-3-iodo-3-deoxyglucoside (13.6 g., 80%)	176
C₁₅H₁₁O₂Cl			
α -(2-Chlorophenyl)- β -benzoyl-ethylene oxide (15.0 g.)	C ₆ H ₅ MgBr (2.8 g. Mg)	Recovered oxidoketone (2.0 g.); 1,1-diphenyl-2,3-epoxy-3- <i>o</i> -chlorophenyl-1-propanol (13.5 g.)	171
C₁₅H₁₂O₂			
Benzylideneacetophenone oxide (35 g.)	C ₂ H ₅ MgBr (5.0 equiv.)	C ₆ H ₅ (C ₂ H ₅) ₂ COH (17 g., 66%); gum	85

* Identical with that obtained by reduction of C₂H₅(C₆H₅)CHCOC₆H₅.† Identical with that obtained from C₂H₅(C₆H₅)CHCHO + C₆H₅MgBr.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₁₂O₂ (<i>cont.</i>)			
Benzylideneacetophenone oxide (34 g.)	C ₆ H ₅ MgBr (47 g. C ₆ H ₅ Br)	1,1,3-Triphenyl-2,3-epoxy-1-propanol (22 g.)	85
Benzylideneacetophenone oxide	C ₆ H ₅ MgBr (5.0 equiv.)	(C ₆ H ₅) ₃ COH (<i>ca.</i> 70%); gum	85
C₁₅H₂₄O			
Copaene oxide* (7.30 g.)	CH ₃ MgI (3.0 equiv.)	2,8,9-Trimethyl-5-isopropyltri- cyclo[4.4.0.0 ^{2,4}]decan-8-ol (6.43 g., 82%, crude)	16
Cadinene monoxide† (44.5 g.)	CH ₃ MgCl (excess)	After Se dehydrogen'n: "monomethyl- cadalene"‡	20
C₁₅H₂₄O₂			
Cadinene dioxide§ (35.5 g.)	CH ₃ MgCl (36.0 g. Mg)	After Se dehydrogen'n: "dimethyl- cadalene"¶ (0.6 g., crude)	20
C₁₆H₁₀O₃			
Benzylidene- <i>p</i> -methoxyacetophenone oxide (5.0 g.)	C ₆ H ₅ MgBr (10.5 ml. C ₆ H ₅ Br)	HO(C ₆ H ₅)(4-CH ₃ OC ₆ H ₄)CCH(C ₆ H ₅)CH (C ₆ H ₅)OH (3.0 g.)	11
C₁₆H₁₄O₃			
α-Phenyl-β- <i>p</i> -anisoylethylene oxide (15.0 g.)	C ₆ H ₅ MgBr (1 equiv.)	Recovered oxidoketone (7.5 g.); (C ₆ H ₅) ₂ CHCH(OH)C(OH)(C ₆ H ₅)C ₆ H ₄ - 4-OCH ₃ , m. 132° (12.0 g.)‡	149

* 1,8-Dimethyl-5-isopropyl-8,9-epoxytricyclo[4.4.0.0^{2,4}]decane.

† 1,6-Dimethyl-1,2-epoxy-4-isopropyl-1,2,3,4,4a,5,8,8a-octahydronaphthalene.

‡ 1,2,6-Trimethyl-4-isopropyl-naphthalene.

§ 1,6-Dimethyl-1,2,6,7-diepoxy-4-isopropyltetralin.

¶ 1,2,6,7-Tetramethyl-4-isopropyl-naphthalene.

‡ Inverse addition at -15°; half-hour stirring.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₆H₁₄O₃ (<i>cont.</i>)			
α -Phenyl- β - <i>p</i> -anisylethylene oxide (15.0 g.)	C ₆ H ₅ MgBr (4 equiv.)	(C ₆ H ₅) ₂ CHCH(OH)C(OH)(C ₆ H ₅)C ₆ H ₄ -4-OCH ₃ , m. 132° (23.5 g.)*	149
C₁₇H₁₆O₃			
Ethyl β,β -diphenylglycidate†	C ₆ H ₅ MgBr ("large excess")	(C ₆ H ₅) ₃ COH; (C ₆ H ₅) ₂ CHCHO; (C ₆ H ₅ —) ₂	85
C₁₈H₂₁O₂N			
Desoxycodine-C (10.0 g.)	CH ₃ MgI (120 ml., 1.0 M)	Methyldihydrodesoxycodine (5.7 g., 55%)	118
Desoxycodine-C (11.0 g.)	C ₂ H ₅ MgI (240% excess)	α -Ethyldihydrodesoxycodine (3.5 g.)	118
Desoxycodine-C (5.5 g.)	C ₆ H ₅ MgBr (70 ml., 1.0 M)	Phenyldihydrodesoxycodine (5.2 g.); recovered oxide (0.8 g.)	118
Desoxycodine-C (6.8 g.)	(CH ₃) ₅ CHMgCl (150 ml., 0.6 M)	Cyclohexyldihydrodesoxycodine (isolated as perchlorate, 6.8 g.)	118
C₁₉H₃₀O₃			
Δ^5 -3(β),17(α)-Androstanediol 5,6-oxide (0.06 g.)	CH ₃ MgI (1.5 g. CH ₃ I)	6-Methylandrostande-3,5,17-triol	173
C₂₁H₁₆O₂			
Benzylidene- <i>p</i> -phenylacetophenone oxide (10.0 g.)	C ₆ H ₅ MgBr (20 ml. C ₆ H ₅ Br)	[HO(C ₆ H ₅)(4-C ₆ H ₅ C ₆ H ₄)C—] ₂ ; HO(C ₆ H ₅)-(4-C ₆ H ₅ C ₆ H ₄)CCH(C ₆ H ₅)CH(C ₆ H ₅)OH	11
α,β -Epoxy- β,β -diphenylpropio-phenone	C ₂ H ₅ MgI (excess)	(C ₆ H ₅) ₂ CHCHO	85
α,β -Epoxy- β - <i>p</i> -biphenylpropio-phenone (5.0 g.)	C ₆ H ₅ MgBr (12.0 g. C ₆ H ₅ Br)	4-C ₆ H ₅ C ₆ H ₄ (C ₆ H ₅) ₂ COH (2.8 g.); gum	5

* Normal addition; one hour reflux.

† Ethyl α,β -epoxy- β,β -diphenylpropionate; according to Kohler *et al.* (85), the supposed glycidate investigated by Bardon and Ramart (6) was in fact the isomeric glyoxylate, (C₆H₅)₂CHCOCO₂C₂H₅.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₁H₁₆O₂ (cont.)			
α, β -Epoxy- β - <i>p</i> -biphenylpropio- phenone (5.0 g.)	C ₆ H ₅ MgBr + Mg + MgBr ₂	[HO(C ₆ H ₅)(4-C ₆ H ₅ C ₆ H ₄)C—] ₂ (2.0 g.)	5
α, β -Epoxy- β, β -diphenylpropio- phenone	C ₆ H ₅ MgBr (excess)	(C ₆ H ₅) ₂ CHCHO; (C ₆ H ₅) ₂ CHOH	85
1,3,3-Triphenyl-2,3-epoxy-1- propanol	CH ₃ MgI (1.25 equiv.)	C ₆ H ₅ CHO; (C ₆ H ₅) ₂ CHCHO; (C ₆ H ₅) ₂ CHCOCH(C ₆ H ₅)OH (?)	85
1,1,3-Triphenyl-2,3-epoxy-1- propanol	C ₆ H ₅ MgBr (excess)	(C ₆ H ₅) ₃ COH	85
1,3,3-Triphenyl-2,3-epoxy-1- propanol	C ₆ H ₅ MgBr (excess)	(C ₆ H ₅) ₂ CHCHO; (C ₆ H ₅) ₂ CHOH; (C ₆ H ₅ —) ₂	5
C₂₁H₁₇O₂Cl			
1,1-Diphenyl-2,3-epoxy-3- <i>o</i> - chlorophenyl-1-propanol	C ₂ H ₅ MgBr	C ₂ H ₅ (C ₆ H ₅) ₂ COH*	171
C₂₁H₂₄O₂			
α -Mesityl- α -mesitoylethylene oxide	CH ₃ MgI	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC[C ₆ H ₂ -2,4,6- (CH ₃) ₃]=CH ₂ (ca. quant.)	40
α -Mesityl- α -mesitoylethylene oxide	C ₂ H ₅ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC[C ₆ H ₂ -2,4,6- (CH ₃) ₃]=CH ₂ (ca. quant.)	40
α -Mesityl- α -mesitoylethylene oxide	C ₆ H ₅ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC[C ₆ H ₂ -2,4,6- (CH ₃) ₃]=CH ₂ (ca. quant.)	40
α -Mesityl- β -mesitoylethylene oxide	C ₂ H ₅ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CH(C ₂ H ₅)CH(OH)COC ₆ H ₂ - 2,4,6-(CH ₃) ₃ (?)	40

* The formation of this product is interpreted as arising from cleavage of the propoxide initially formed: ROMgBr \rightarrow (C₆H₅)₂CO + C₆H₅CH=CHOMgBr.

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₁H₃₄O₄ 3(β),20,21-Pregnanetriol 5,6-oxide	CH ₃ MgBr	6-Methyl-3(β),5,20,21-pregnanetetrol	157
C₂₁H₃₆O₃ Methyl 1,4a,7-trimethyl-7,8-epoxy-8a-ethylperhydro-1-phenanthrene-carboxylate (4.0 g.)	CH ₃ MgI (40.0 g. CH ₃ I)	1,4a,7,8-Tetramethyl-1-(α -hydroxy-isopropyl)-8a-ethylperhydro-7-phenanthrol	114
C₂₂H₁₈O₃ α , β -Epoxy- β -anisyl- <i>p</i> -phenylpropiophenone	C ₆ H ₅ MgBr + Mg + MgBr ₂	No benzpinacol isolated	5
C₂₂H₂₀O₃ 1,3-Diphenyl-1- <i>p</i> -anisyl-2,3-epoxy-1-propanol (2.0 g.)	C ₆ H ₅ MgBr (3 equiv.)	(C ₆ H ₅) ₂ CHCH(OH)C(OH)(C ₆ H ₅)C ₆ H ₄ -4-OCH ₃ (2.5 g.)	149
C₂₂H₂₆O₂ α -Mesityl- α -isoduroylethylene oxide	CH ₃ MgI	2,3,4,6-(CH ₃) ₄ C ₆ HCOC[C ₆ H ₂ -2,4,6-(CH ₃) ₃]=CH ₂	40
α -Mesityl- α -duroylethylene oxide	CH ₃ MgI	2,3,5,6-(CH ₃) ₄ C ₆ HCOC[C ₆ H ₂ -2,4,6-(CH ₃) ₃]=CH ₂	40
C₂₄H₂₂O₂ α , β -Diphenyl- α -mesitoylethylene oxide	CH ₃ MgI	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC(C ₆ H ₅)=CHC ₆ H ₅	40
C₂₅H₂₄O₂ α , β -Diphenyl- α -duroylethylene oxide	CH ₃ MgI	2,3,5,6-(CH ₃) ₄ C ₆ HCOC(C ₆ H ₅)=CHC ₆ H ₅	40

TABLE XIV-I (Continued)

<u>Epoxide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₇H₄₆O₂			
Cholesterol α -oxide	CH ₃ MgI	6-Methyl-3,5-cholestanediol* (60%)	133
Cholesterol α -oxide	CH ₃ MgI	6-Methylcholesterol†	133
Cholesterol α -oxide	CH ₃ MgI	6(β)-Methylcholestane-3(β),5(α)-diol (40%)	159; cf. 152
Cholesterol α -oxide	C ₆ H ₅ MgBr	6-Oxo-3-cholestanol‡	22
Cholesterol β -oxide	CH ₃ MgI	5(α)-Methyl-3(β),6(β)-cholestanediol	160,152
C₂₈H₂₂O			
9,10-Epoxy-9,10-dibenzyl-9,10-dihydrophenanthrene (5 g.)	C ₂ H ₅ MgBr (4 g. C ₂ H ₅ Br)	9,10-Dibenzyl-10-ethyl-9-phenanthrol	139
C₄₀H₅₆O			
β -Carotene monoëpoxide	CH ₃ MgI (excess)	Mutatochrome	77
C₄₀H₅₆O₂			
β -Carotene diëpoxide	CH ₃ MgI (excess)	Aurochrome	77
C₄₀H₅₆O₄			
Violoxanthin	CH ₃ MgI (excess)	Auroxanthin	77

* Five hours reflux in C₆H₆.† Seven hours reflux in C₆H₆.‡ Two hours reflux in C₆H₆.

REFERENCES FOR TABLE XIV-I

- (1) Arbuzov, *J. Gen. Chem.* (U.S.S.R.), 9, 249-54 (1939); *Chem. Abstr.*, 33, 6279 (1939).
- (2) Bachman and Lewis, *J. Am. Chem. Soc.*, 69, 2022-5 (1947).
- (3) Bachman and Thomas, *J. Am. Chem. Soc.*, 64, 94-7 (1942).
- (4) Bachman, *J. Am. Chem. Soc.*, 57, 382-3 (1935).
- (5) Bachmann and Wiselogle, *J. Am. Chem. Soc.*, 56, 1559-60 (1934).
- (6) Bardon and Ramart, *Compt. rend.*, 183, 214-6 (1926).
- (7) Bartlett and Berry, *J. Am. Chem. Soc.*, 56, 2683-5 (1934).
- (8) Bedos, *Bull. soc. chim.*, [4], 39, 292-305 (1926).
- (9) Bedos, *Bull. soc. chim.*, [4], 39, 473-87 (1926).
- (10) Bedos, *Compt. rend.*, 228, 1441-3 (1949); *Chem. Abstr.*, 43, 7431 (1949).
- (11) Bergmann and Wolff, *J. Am. Chem. Soc.*, 54, 1644-7 (1932).
- (12) Blaise, *Compt. rend.*, 134, 551-3 (1902); *Chem. Zentr.*, 1902, 1, 856.
- (13) Bogert and Sterling, *Science*, 87, 196, 234 (1938); *Chem. Abstr.*, 32, 4147 (1938).
- (14) Bousset, *Bull. soc. chim.*, [5], 1, 1305-8 (1934).
- (15) Boyd and Vineall, *J. Chem. Soc.*, 1929, 1622.
- (16) Briggs and Taylor, *J. Chem. Soc.*, 1947, 1338-9.
- (17) Buu-Hoi and Cagniant, *Bull. soc. chim.*, [5], 11, 349-54 (1944).
- (18) Buu-Hoi, Cagniant, and Mentzer, *Bull. soc. chim.*, [5], 11, 127-36 (1944).
- (19) Cagniant and Deluzarche, *Compt. rend.*, 224, 473-4 (1947); *Chem. Abstr.*, 41, 5100 (1947).
- (20) Campbell and Soffer, *J. Am. Chem. Soc.*, 64, 417-25 (1943).
- (21) Cason, Adams, Bennett, and Register, *J. Am. Chem. Soc.*, 66, 1764-7 (1944).
- (22) Chinaeva and Ushakov, *J. Gen. Chem.* (U.S.S.R.), 11, 335-8 (1941); *Chem. Abstr.*, 35, 5903 (1941).
- (23) Cook, Haslewood, and Robinson, *J. Chem. Soc.*, 1935, 667-71.
- (24) Cook, Hewett, and Lawrence, *J. Chem. Soc.*, 1936, 71-80.
- (25) Cook and Robinson, *J. Chem. Soc.*, 1938, 505-13.
- (26) Cottle and Hollyday, *J. Org. Chem.*, 12, 510-6 (1947).
- (27) Cottle and Powell, *J. Am. Chem. Soc.*, 58, 2267-72 (1936).
- (28) Danehy, Vogt, and Nieuwland, *J. Am. Chem. Soc.*, 56, 2790 (1934).
- (29) Delaby, *Compt. rend.*, 176, 1153-6 (1923).
- (30) Delaby, *Ann. chim.*, [9], 20, 33-81 (1923).
- (31) Dreger, *Organic Syntheses*, 6, 54-7 (1926); *Coll. Vol. I*, 1st ed., 298-301 (1932); 2nd ed., 306-8 (1941).
- (32) Elderfield, Craig, Lauer, Arnold, Gensler, Head, Bembry, Mighton, Tinker, Galbreath, Holley, Goldman, Maynard, and Pincus, *J. Am. Chem. Soc.*, 68, 1516-23 (1946).
- (33) Faucounau, *Compt. rend.*, 199, 605-7 (1934); *Chem. Abstr.*, 28, 7245 (1934).
- (34) Fordyce and Johnson, *J. Am. Chem. Soc.*, 55, 3368-72 (1933).
- (35) Fosdick, Fancher, and Urbach, *J. Am. Chem. Soc.*, 68, 840-3 (1946).
- (36) Fourneau and Tiffeneau, *Compt. rend.*, 145, 437-9 (1907); *Chem. Zentr.*, 1907, 11, 1320.
- (37) Fourneau and Tiffeneau, *Bull. soc. chim.*, [4], 1, 1227-33 (1907).
- (38) Freedman and Becker, *J. Org. Chem.*, 16, 1701-11 (1951).
- (39) Fulton and Robinson, *J. Chem. Soc.*, 1933, 1463-6.
- (40) Fuson, Byers, Sperati, Foster, and Warfield, *J. Org. Chem.*, 10, 69-75 (1945).
- (41) Gaylord and Becker, *J. Org. Chem.*, 15, 305-16 (1950).
- (42) Gmitter and Benton, *J. Am. Chem. Soc.*, 72, 4586-9 (1950).
- (43) Godchot and Bedos, *Compt. rend.*, 174, 461-4 (1922).
- (44) Godchot and Bedos, *Compt. rend.*, 175, 1411-5 (1922).
- (45) Godchot and Bedos, *Compt. rend.*, 180, 751-4 (1925).
- (46) Godchot and Bedos, *Compt. rend.*, 182, 393-5 (1926).

- (47) Godchot and Bedos, *Compt. rend.*, 184, 208-10 (1927).
(48) Godchot and Bedos, *Bull. soc. chim.*, [4], 37, 1451-66 (1925).
(49) Godchot and Bedos, *Bull. soc. chim.*, [4], 37, 1637-51 (1925).
(50) Godchot and Bedos, *Bull. soc. chim.*, [4], 43, 521-2 (1928).
(51) Golumbic and Cottle, *J. Am. Chem. Soc.*, 61, 996-1000 (1939).
(52) Grignard, *Bull. soc. chim.*, [3], 29, 944-8 (1903).
(53) Grignard, *Compt. rend.*, 136, 1260-2 (1903); *Chem. Zentr.*, 1903,I, 105.
(54) Haworth and Barker, *J. Chem. Soc.*, 1939, 1299-303.
(55) Haworth, Mavin, and Sheldrick, *J. Chem. Soc.*, 1934, 454-61.
(56) Henry, *Compt. rend.*, 144, 308-13 (1907); *Chem. Zentr.*, 1907,I, 1102.
(57) Henry, *Compt. rend.*, 145, 21-5 (1907); *Chem. Zentr.*, 1907,II, 889.
(58) Henry, *Compt. rend.*, 145, 154-6 (1907); *J. Chem. Soc.*, 92,I, 745 (1907).
(59) Henry, *Compt. rend.*, 145, 406-8 (1907); *Chem. Zentr.*, 1907,II, 1320.
(60) Henry, *Compt. rend.*, 145, 453-6 (1907); *Chem. Zentr.*, 1907,II, 1320.
(61) Henry, *Bull. acad. roy. Belg., Classe sci.*, 1907, 162-89; *Chem. Zentr.*, 1907,II, 445.
(62) Hess, *Ber.*, 46, 3113-25 (1913).
(63) Hiers and Adams, *J. Am. Chem. Soc.*, 48, 1089-93 (1926).
(64) Holliman and Mann, *J. Chem. Soc.*, 1942, 737-4.
(65) Holliman and Mann, *J. Chem. Soc.*, 1947, 1634-42.
(66) Horeau and Jacques, *Bull. soc. chim.*, [5], 13, 382-5 (1946).
(67) Hoshino and Shimodaira, *Ann.*, 520, 19-30 (1935).
(68) Huston and Agett, *J. Org. Chem.*, 6, 123-33 (1941).
(69) Huston and Bostwick, *J. Org. Chem.*, 13, 331-8 (1948).
(70) Huston and Brault, *J. Org. Chem.*, 15, 1211-8 (1950).
(71) Huston and Langham, *J. Org. Chem.*, 12, 90-5 (1947).
(72) Huston and Tiefenthal, *J. Org. Chem.*, 16, 673-8 (1951).
(73) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 34, 96-8 (1902); *Bull. soc. chim.*, [3], 28, 920 (1902).
(74) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 35, 554-5 (1903); *Bull. soc. chim.*, [3], 32, 740 (1904).
(75) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 36, 6-8 (1904); *Bull. soc. chim.*, [3], 34, 185 (1905).
(76) Iotsitch, Breitfous, Roudolf, Stassévitch, Elmanovitch, Kondyref, and Fomine, *J. Russ. Phys.-Chem. Soc.*, 39, 652-7 (1907); *Bull. soc. chim.*, [4], 6, 98 (1909).
(77) Karrer, Jucker, and Steinlein, *Helv. Chim. Acta*, 29, 233-6 (1946).
(78) Kayser, *Compt. rend.*, 196, 1127-9 (1933).
(79) Kayser, *Compt. rend.*, 199, 1424-7 (1934).
(80) Khaletzkii, *J. Gen. Chem. (U.S.S.R.)*, 6, 1-14 (1936); *Chem. Abstr.*, 30, 4844 (1936).
(81) Kharasch and Clapp, *J. Org. Chem.*, 3, 355-60 (1938).
(82) Kling, *Bull. soc. chim.*, [3], 31, 14-6 (1904).
(83) Koelsch and McElvain, *J. Am. Chem. Soc.*, 51, 3390-4 (1929).
(84) Koelsch and McElvain, *J. Am. Chem. Soc.*, 52, 1164-9 (1930).
(85) Kohler, Richtmyer, and Hester, *J. Am. Chem. Soc.*, 53, 205-21 (1931).
(86) Kon and Woolman, *J. Chem. Soc.*, 1939, 794-800.
(87) Levene and Walti, *J. Biol. Chem.*, 90, 81-8 (1931); *Chem. Abstr.*, 25, 1818 (1931).
(88) Levene and Walti, *J. Biol. Chem.*, 94, 367-73 (1931).
(89) Magrane and Cottle, *J. Am. Chem. Soc.*, 64, 484-7 (1942).
(90) Mair, *Bur. Standards J. Research*, 9, 457-72 (1922).
(91) Malinovskii, Volkova, and Morozova, *J. Gen. Chem. (U.S.S.R.)*, 19, 114-7 (1949); *Chem. Abstr.*, 43, 6155 (1949).
(92) Manske and Ledingham, *Can. J. Research*, 27, 158-60 (1949).

- (93) Marvel, Blomquist, and Vaughn, *J. Am. Chem. Soc.*, 50, 2810-2 (1928).
(94) Marvel and Hein, *J. Am. Chem. Soc.*, 70, 1895-8 (1948).
(95) Meisenheimer, *Ann.*, 442, 180-210 (1925).
(96) Natelson and Gottfried, *J. Am. Chem. Soc.*, 61, 1001-2 (1939).
(97) Nazarov and Elizarova, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1940, 189-94; *Chem. Abstr.*, 36, 741 (1942).
(98) Newman, *J. Am. Chem. Soc.*, 62, 2295-300 (1940).
(99) Newman, *J. Org. Chem.*, 9, 518-28 (1944).
(100) Newman, Magerlein, and Wheatley, *J. Am. Chem. Soc.*, 68, 2112-5 (1946).
(101) Normant, *Compt. rend.*, 219, 163-4 (1944); *Chem. Abstr.*, 40, 4041 (1946).
(102) Norris and Cortese, *J. Am. Chem. Soc.*, 49, 2640-50 (1927).
(103) Norton and Hass, *J. Am. Chem. Soc.*, 58, 2147-50 (1936).
(104) Oddo and Cambieri, *Gazz. chim. ital.*, 69, 19-24 (1939); *Chem. Abstr.*, 33, 4239 (1939).
(105) Pockivas and Tchoubar, *Compt. rend.*, 205, 287-8 (1937); *Chem. Abstr.*, 31, 7853 (1937).
(106) Prilezhaev and Vershuk, *J. Russ. Phys.-Chem. Soc.*, 61, 473-82 (1929); *Chem. Abstr.*, 23, 4463 (1929).
(107) Quelet and Golse, *Compt. rend.*, 224, 661-3 (1947); *Chem. Abstr.*, 41, 4779 (1947).
(108) Rajagopalan, *J. Indian Chem. Soc.*, 17, 567-72 (1940).
(109) Ribas, *Anales soc. españ. fís. quim.*, 26, 122-32 (1928); *Chem. Zentr.*, 1928,II, 40.
(110) Wiggins and Wood, *J. Chem. Soc.*, 1950, 1566-75.
(111) Ritter and Russell, *J. Am. Chem. Soc.*, 58, 291-3 (1936).
(112) Robinson, *J. Chem. Soc.*, 1936, 80.
(113) Ruzicka, Ehmann, and Morgeli, *Helv. Chim. Acta*, 16, 314-26 (1933).
(114) Ruzicka and Sternbach, *Helv. Chim. Acta*, 23, 124-31 (1940).
(115) Semeniuk and Jenkins, *J. Am. Pharm. Assoc., Sci. Ed.*, 37, 118-21 (1948); *Chem. Abstr.*, 42, 5410 (1948).
(116) Sharefkin and Ritter, *J. Am. Chem. Soc.*, 63, 1478-9 (1941).
(117) Shorugin and Isagulyantz, *Trans. VI Mendeleev Congr. Theoret. Applied Chem.* 1932, 2, Pt. 1, 973-80 (1935); *Chem. Abstr.*, 30, 4157 (1936).
(118) Small and Yuen, *J. Am. Chem. Soc.*, 58, 192-6 (1936).
(119) Smith and Agre, *J. Am. Chem. Soc.*, 60, 648-52 (1938).
(120) Smith and Miller, *J. Am. Chem. Soc.*, 64, 440-5 (1942).
(121) Smith and Miller, U. S. Patent 2,372,132, March 20, 1945; *Chem. Abstr.*, 39, P4894 (1945).
(122) Smith, Wawzonek, and Miller, *J. Org. Chem.*, 6, 229-35 (1941).
(123) Sobotka and Chanley, *J. Am. Chem. Soc.*, 70, 3914-8 (1948).
(124) Sontag, *Ann. chim.*, [11], 1, 359-438 (1934).
(125) Stahl and Cottle, *J. Am. Chem. Soc.*, 65, 1782-3 (1943).
(126) Stevens and McCoubrey, *J. Am. Chem. Soc.*, 63, 2847-8 (1941).
(127) Stoll and Rouvé, *Helv. Chim. Acta*, 21, 1542-7 (1938).
(128) Tapia and Hernández, *Anales. soc. españ. fís. quim.*, 28, 691-3 (1930); *Chem. Zentr.*, 1930,II, 1697.
(129) Taub, Wiegler, and Schulemann, German Patent 423,544, Jan. 9, 1926; *Chem. Zentr.*, 1926,I, 3635.
(130) Tiffeneau, *Compt. rend.*, 140, 1458-60 (1905); *Chem. Zentr.*, 1905,II, 235.
(131) Tiffeneau and Fourneau, *Compt. rend.*, 146, 697-9 (1908); *Chem. Zentr.*, 1908,I, 1776.
(132) Tiffeneau and Tchoubar, *Compt. rend.*, 212, 581-5 (1941); *Chem. Zentr.*, 1942,I, 610; *Chem. Abstr.*, 37, 2720 (1943).
(133) Ushakov and Madaeva, *J. Gen. Chem. (U.S.S.R.)*, 9, 436-41 (1939); *Chem. Abstr.*, 33, 9309 (1939).

- (134) Vaughn, Spahr, and Nieuwland, *J. Am. Chem. Soc.*, 55, 4207-9 (1933).
- (135) Vavon and Mitchovitch, *Bull. soc. chim.*, [4], 37, 1451-66 (1925).
- (136) Vavon and Mitchovitch, *Compt. rend.*, 186, 702-5 (1928); *Chem. Abstr.*, 22, 2552 (1928).
- (137) Veibel, Lundqvist, Andersen, and Frederiksen, *Bull. soc. chim.*, [5], 6, 990-8 (1939).
- (138) Zincke and Schwabe, *Ber.*, 41, 897-902 (1908).
- (139) Zincke and Tropp, *Ann.*, 362, 242-59 (1908).
- (140) Altwegg, U. S. Patent 1,315,619, Sept. 9, 1919; *Chem. Abstr.*, 13, P2883 (1919).
- (141) Turner, *J. Am. Chem. Soc.*, 72, 878-82 (1950).
- (142) Bedos, *Bull. soc. chim.*, [4], 33, 163-4 (1923).
- (143) Bedos, *Compt. rend.*, 177, 111-3 (1923); *Chem. Abstr.*, 17, 3177 (1923).
- (144) Bedos, *Compt. rend.*, 177, 958-60 (1923); *Chem. Abstr.*, 18, 532 (1924).
- (145) Bedos, *Compt. rend.*, 181, 117-9 (1925); *Chem. Abstr.*, 19, 3266 (1925).
- (146) Bedos, *Bull. soc. chim.*, [4], 39, 674-90 (1926).
- (147) Beeby and Mann, *J. Chem. Soc.*, 1951, 411-5.
- (148) Bergmann and Blum-Bergmann, *J. Am. Chem. Soc.*, 58, 1678-81 (1936).
- (149) Bickel, *J. Am. Chem. Soc.*, 59, 325-8 (1937).
- (150) Cason and Winans, *J. Org. Chem.*, 15, 139-47 (1950).
- (151) Chavanne and de Vogel, *Bull. soc. chim. Belg.*, 37, 141-52 (1928).
- (152) Chuman, *J. Chem. Soc. Japan, Pure Chem. Sect.*, 70, 253-7 (1949); *Chem. Abstr.*, 45, 6651 (1951).
- (153) Cohen, Cook, Hewett, and Girard, *J. Chem. Soc.*, 1934, 653-8.
- (154) Cook and Hewett, *J. Chem. Soc.*, 1933, 1098-111.
- (155) Danehy, Vogt, and Nieuwland, *J. Am. Chem. Soc.*, 57, 2327 (1935).
- (156) Dice, Watkins, and Schuman, *J. Am. Chem. Soc.*, 72, 1738-40 (1950).
- (157) Ehrenstein, *J. Org. Chem.*, 8, 83-94 (1943).
- (158) Elderfield, Pitt, and Wempen, *J. Am. Chem. Soc.*, 72, 1334-45 (1950).
- (159) Fieser and Rigaudy, *J. Am. Chem. Soc.*, 73, 4660-2 (1951).
- (160) Urishibara and Chuman, *Bull. soc. chim. Japan*, 22, 69-74 (1949); *Chem. Abstr.*, 44, 1124 (1950).
- (161) Fourneau, Tréfouel, and Tréfouel, *Bull. soc. chim.*, [4], 43, 454-8 (1928).
- (162) Frank, Adams, Allen, Gander, and Smith, *J. Am. Chem. Soc.*, 68, 1365-8 (1946).
- (163) Gilman and Abbott, *J. Org. Chem.*, 8, 224-9 (1943).
- (164) Gilman and Kirby, *J. Am. Chem. Soc.*, 54, 345-55 (1932).
- (165) Godchot and Bedos, *Bull. soc. chim.*, [4], 33, 162-3 (1923).
- (166) Godchot, Bedos, and Cauquil, *Bull. soc. chim.*, [4], 43, 521-2 (1928).
- (167) Harlow and Britton, U. S. Patent 1,591,125, July 6, 1926; *Chem. Abstr.*, 20, P3171 (1926).
- (168) Hiers and Adams, *J. Am. Chem. Soc.*, 48, 2385-95 (1926).
- (169) I. G. Farbenindustrie A.-G., French Patent 807,632, Jan. 1, 1937; *Chem. Zentr.*, 1937, I, 4022.
- (170) Kayser, *Ann. chim.*, [11], 6, 145-248 (1936).
- (171) Kohler and Bickel, *J. Am. Chem. Soc.*, 57, 1099-101 (1935).
- (172) Letsinger, Traynham, and Bobko, *J. Am. Chem. Soc.*, 74, 399-401 (1952).
- (173) Madaeva, Ushakov, and Kosheleva, *J. Gen. Chem. (U.S.S.R.)*, 10, 213-6 (1940); *Chem. Zentr.*, 1940, II, 1298; *Chem. Abstr.*, 34, 7292 (1940).
- (174) Malinovskii and Konevichev, *J. Gen. Chem. (U.S.S.R.)*, 18, 1833-5 (1948); *Chem. Abstr.*, 43, 3776 (1949).
- (175) Mousseron and Du, *Bull. soc. chim.*, [5], 15, 91-6 (1948).
- (176) Newth, Richards, and Wiggins, *J. Chem. Soc.*, 1950, 2356-64.
- (177) Plate, Shafran, and Batuev, *J. Gen. Chem. (U.S.S.R.)*, 20, 472-8 (1950); *Chem. Abstr.*, 44, 7785 (1950).
- (178) Price and Halpern, *J. Am. Chem. Soc.*, 73, 818-20 (1951).

- (179) Prilezhaev and Prokopchuk, *J. Gen. Chem.* (U.S.S.R.), 3, 865-8 (1933); *Chem. Abstr.*, 28, 6133 (1934).
- (180) Riedel A.-G., German Patent 183,361, Feb. 25, 1907; *Friedlaender*, 8, 1041-2 (1905-1907); *Chem. Zentr.*, 1907,1, 1607.
- (181) Rothman and Becker, Unpublished results, as cited by Gaylord and Becker, *Chem. Revs.*, 49, 413-533 (1951).
- (182) Ruzicka, Ehmann, Goldberg, and Hösli, *Helv. Chim. Acta*, 16, 833-41 (1933).
- (183) Schinz and Simon, *Helv. Chim. Acta*, 28, 774-80 (1945).
- (184) Schorigin, Issaguljanz, Gussewa, Ossipowa, and Poljakowa, *Ber.*, 64B, 2584-90 (1931).
- (185) Smith and Fuzek, *J. Am. Chem. Soc.*, 72, 3454-8 (1950).
- (186) Sobotka and Slynler, *J. Am. Chem. Soc.*, 72, 5139-43 (1950).
- (187) Soc. chim. usines Rhone, British Patent 122,630, Jan. 3, 1919; *Chem. Abstr.*, 13, P1715 (1919).
- (188) Sommer, Van Strien, and Whitmore, *J. Am. Chem. Soc.*, 71, 3056-60 (1949).
- (189) Truce and Wise, *J. Am. Chem. Soc.*, 72, 2300 (1950).
- (190) Stevens and Pratt, Abstracts of Papers, 119th Meeting, A.C.S., Cleveland, Ohio, April, 1951, p. 92M.
- (191) Szmant, Anzenberger, and Hartle, *J. Am. Chem. Soc.*, 72, 1419-20 (1950).
- (192) Temnikova and Kropacheva, *J. Gen. Chem.* (U.S.S.R.), 21, 183-6 (1951); *Chem. Abstr.*, 45, 7046 (1951).
- (193) Blicke and Burckhalter, *J. Am. Chem. Soc.*, 64, 477-80 (1942).
- (194) Gaertner, *J. Am. Chem. Soc.*, 73, 3934-7 (1951).
- (195) Newman and Wotiz, *J. Am. Chem. Soc.*, 71, 1292-7 (1949).
- (196) Gilman and Towle, *Rec. trav. chim.*, 69, 428-32 (1950).
- (197) Gaertner, *J. Am. Chem. Soc.*, 74, 2185-8 (1952).

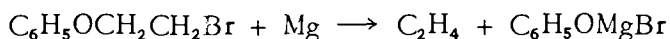
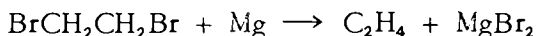
CHAPTER XV

Reactions of Grignard Reagents with Ethers, Acetals, and Ketals

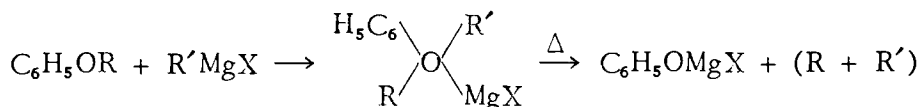
CLEAVAGES OF ACYCLIC ETHERS

In the attempt to prepare an organomagnesium bromide from β -bromoethoxybenzene Grignard¹ obtained only ethylene, phenol, and a trace of 1,4-diphenoxybutane. The attempt to condense this bromide with *n*-amylmagnesium bromide was similarly unsuccessful, and likewise resulted in the production of phenol. With benzylmagnesium chloride the attempt was only partially successful, resulting in the production of considerable phenol. Grignard reported *n*-amyl alcohol and benzyl alcohol, respectively, as co-products of these reactions, but any of these alcohols detected must have been due to oxygen contamination (see Chapter XX).

Grignard² believed that the Grignard reagent of β -bromoethoxybenzene is formed but immediately undergoes an ether-cleavage reaction with unchanged bromide. It is at least equally probable, however, that this reaction is a special case of internal Wurtz reaction (analogous to that undergone by ethylene bromide), with the phenoxy group playing the rôle of a "pseudohalogen" (see Chapter II, Limitations of the Classical Method).



Grignard (*loc. cit.*²) showed, however, that such ethers as phenetole, estragole (4-methoxyallylbenzene), and 3,4-dimethoxyallylbenzene undergo cleavage when heated to a sufficiently high temperature with ethylmagnesium bromide, yielding the corresponding phenols. He regarded this phenomenon as constituting additional support for his ether-complex theory and for the constitution assigned by him to the Grignard reagent-ether complexes (see Chapter IV). In general the cleavage of a phenolic ether by an aliphatic Grignard reagent was characterized by him as follows:



$(\text{R} + \text{R}') \rightarrow$ Disproportionation products

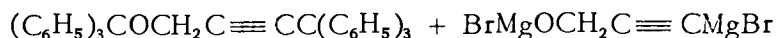
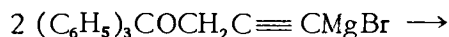
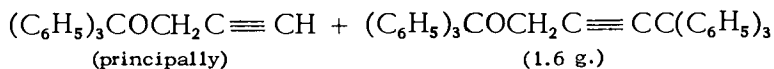
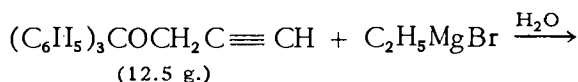
¹ Grignard, *Compt. rend.*, 138, 1048-50 (1904); *Chem. Zentr.*, 1904, I, 1493.

² Grignard, *Compt. rend.*, 151, 322-5 (1910); *Chem. Zentr.*, 1910, II, 1048.

Stadnikoff (Stadnikow, Stadnikov)³ carried out a series of studies on the reactions of aliphatic Grignard reagents with the alkyl ethers of benzhydrol. In all cases symmetrical tetraphenylethane was reported as one of the principal products.* Stadnikoff, like Grignard, believed that the intermediate product in such reactions is an ether-Grignard reagent complex, but maintained that actual cleavage of the ether takes place during the process of hydrolysis.

Tschelinzew⁴ showed, however, that cleavage products of the ethyl ethers of benzyl alcohol and benzhydrol, treated with *n*-propylmagnesium iodide, are present prior to hydrolysis.

It may be mentioned in passing, incidentally, that a byproduct observed by Zeile and Meyer⁵ as arising from the treatment of 3-triphenylmethoxypropyne with ethylmagnesium bromide is readily explicable as the result of an ether cleavage.



The question, of course, arises as to which of the components of the Schlenk equilibrium is the effective one (or the most effective one). Schönberg and Moubasher⁶ propose that the cleavage is effected by the magnesium halide present.

Some qualitative evidence may be advanced in support of this hypothesis. Gilman and Schulze⁷ had found that, although a refluxing ethyl ethereal solution of benzyl phenyl ether appears to be stable toward anhydrous magnesium bromide, cleavage takes place slowly in a higher-boiling benzene solution. Grignard and Ritz⁸ have shown that anisole

³ (a) Stadnikoff, *Ber.*, 44, 1157-60 (1911); (b) Stadnikov, *J. Russ. Phys.-Chem. Soc.*, 43, 1244-57 (1911); *Chem. Abstr.*, 6, 1434 (1912); (c) Stadnikow, *J. Russ. Phys.-Chem. Soc.*, 44, 1219-47 (1912); *Chem. Zentr.*, 1913, I, 21; *Chem. Abstr.*, 7, 983 (1913); (d) Stadnikoff, *J. prakt. Chem.*, [2], 88, 1-20 (1913); (e) Stadnikoff and Kusmina-Aron, *ibid.*, [2], 88, 20-5 (1913); (f) Stadnikoff, *Ber.*, 46, 2496-503 (1913); (g) Stadnikow, *J. Russ. Phys.-Chem. Soc.*, 45, 1391-414 (1913); *Chem. Zentr.*, 1913, II, 2120.

*Like the hexaphenylethane of Gomberg and Kamm,¹³ tetraphenylethane is undoubtedly the product of a "coupling" reaction (*q.v.*, Chapter XVI). In this case the source is probably benzhydrol halide, originating in magnesium halide cleavage of the benzhydrol ether.

⁴ Tschelinzew and Pawlow, *J. Russ. Phys.-Chem. Soc.*, 45, 289-300 (1913); *Chem. Zentr.*, 1913, I, 1962; *Chem. Abstr.*, 7, 2227 (1913); *J. Chem. Soc.*, 104, I, 461 (1913).

⁵ Zeile and Meyer, *Ber.*, 75B, 356-62 (1942).

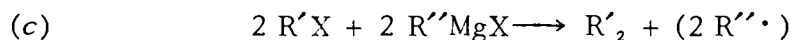
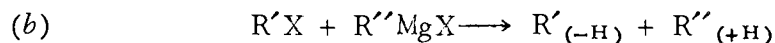
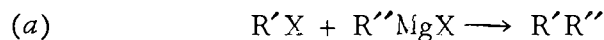
⁶ Schönberg and Moubasher, *J. Chem. Soc.*, 1944, 462-3.

⁷ Gilman and Schulze, *Rec. trav. chim.*, 47, 752-60 (1928).

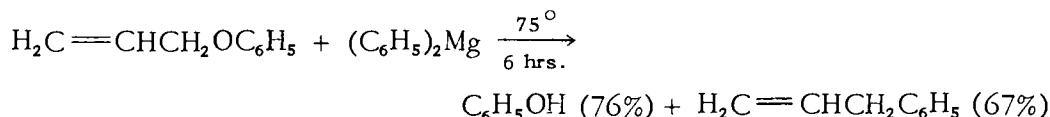
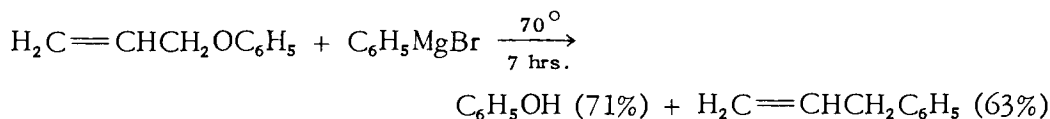
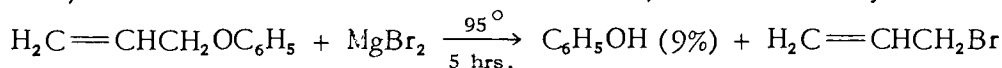
⁸ Grignard and Ritz, *Bull. soc. chim.*, [5], 3, 1181-4 (1936).

undergoes cleavage when heated with magnesium iodide. Moreover, it would seem that one of the simplest and most plausible ways of accounting for symmetrical tetraphenylethane as a major product of Stadnikoff's (*loc. cit.*³) benzhydryl ether cleavages would be to assume that benzhydryl halide is formed by magnesium halide cleavage of the ether and then undergoes a "coupling" reaction (*q.v.*, Chapter XVI). Schönberg and Moubasher (*loc. cit.*⁶) confirmed the observation of Grignard and Ritz (*loc. cit.*⁸), and showed that magnesium bromide behaves similarly, though less effectively.*

It may be further conceded that the products, other than ROH, resulting from the reaction of an unsymmetrical ether (ROR') with a Grignard reagent (R''MgX) are in general (qualitatively) those which might be expected to result from one or more of the possible reactions of the Grignard reagent with the corresponding halide, R'X (see Chapter XVI).



Insofar as data are available for quantitative comparisons, however, the case for the Schönberg and Moubasher hypothesis does not appear quite so persuasive. There is, for example, no sufficient evidence that ethers *in general* react preferentially with the magnesium halide constituent of the Grignard reagent. Indeed, the observations of Schönberg and Moubasher (*loc. cit.*⁶) on the reaction of allyl phenyl ether with magnesium bromide and of Lüttringhaus *et al.* on the reactions of the same ether with phenylmagnesium bromide⁹ and diphenylmagnesium¹⁰ indicate that, for some reactant combinations at least, the reverse may be true.



For a comparison of the products of reactions of Grignard reagents with ethers, on the one hand, and with halides corresponding to the ethers, on the other, data are fragmentary and inconclusive. Stadnikow (*loc. cit.*^{3f,g}) reports that, under conditions not precisely described, methylmagnesium iodide reacts with *n*-butyl benzhydryl ether to give a 42 percent yield of symmetrical tetraphenylethane (with 42 percent ether recovery). Späth¹¹ reports that when benzhydryl bromide is added slowly

* Conceivably this is a solubility rather than a reactivity effect.

⁹ Lüttringhaus, von Sääf, and Hauschild, *Ber.*, 71B, 1673-81 (1938).

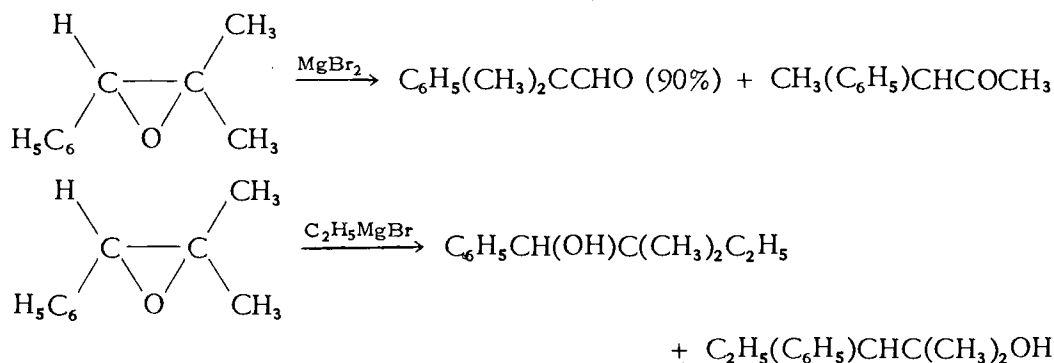
¹⁰ Lüttringhaus, Wagner-von Sääf, Sucker, and Borth, *Ann.*, 557, 46-69 (1945).

¹¹ Späth, *Monatsh.*, 34, 1965-2014 (1913).

to an ethereal solution of methylmagnesium bromide an 85 percent yield of the condensation product (1,1-diphenylethane) was obtained, together with a small amount of coupling product (*sym.*-tetraphenylethane). However, in view of the fact that methylmagnesium iodide is an excellent coupling reagent, whereas methylmagnesium bromide is not,¹² the discrepancy is probably more apparent than real. According to Späth, benzhydriyl bromide with ethylmagnesium bromide gives a 30 percent yield of the condensation product (1,1-diphenylpropane), but only 15.7 percent with ethylmagnesium iodide. Unfortunately the relative amounts of coupling product for the two cases cannot be compared because the value given for the bromide is an obvious misprint. The value for the iodide corresponds to 74 percent.

According to Gomberg and Kamm¹³ treatment of triphenylmethyl chloride with phenylmagnesium bromide by the usual procedure leads to maximum yields of 5 percent of the condensation product (tetraphenylmethane), the major product being that resulting from coupling (hexaphenylethane). When heated to 200° with phenylmagnesium bromide, however, phenyl triphenylmethyl ether yields 15 to 20 percent of tetraphenylmethane. (The experimental conditions, of course, are not comparable.¹⁴)

At best the Schönberg and Moubasher hypothesis merits a Scottish verdict—"not proven." If one may properly draw any conclusions from the very special case of the epoxides (*q.v.*, Chapter XIV), it seems possible, even probable, that some ethers may react preferentially with magnesium halide and others with the Grignard reagent itself. It has been definitely established that ethylene oxide reacts preferentially with magnesium bromide in the presence of ethylmagnesium bromide,¹⁵ for example. This cannot be true of 1-phenyl-2-methyl-1,2-epoxybutane, however, for the products of reaction of ethylmagnesium bromide with that epoxide are not those which would be formed by further reaction of the magnesium bromide cleavage products with ethylmagnesium bromide or diethylmagnesium.¹⁶



¹² Kharasch, Morrison, and Urry, *J. Am. Chem. Soc.*, 66, 368-71 (1944).

¹³ Gomberg and Kamm, *J. Am. Chem. Soc.*, 39, 2009-15 (1917).

¹⁴ Cf. Schoepfle and Trepp, *J. Am. Chem. Soc.*, 58, 791-4 (1936).

¹⁵ Huston and Agett, *J. Org. Chem.*, 6, 123-33 (1941).

¹⁶ Pictavas and Tchoubar, *Compt. rend.*, 205, 287-8 (1937); *Chem. Abstr.*, 31, 7853 (1937).

TABLE XV-I
REACTIONS OF GRIGNARD REAGENTS ($R''MgX$) WITH ACYCLIC ETHERS (ROR')
(In general, R is adjudged more "electronegative" than R' .)

<u>ROR'</u>	<u>$R''MgX$ (or MgX_2)</u>	<u>Temp. (Time)</u>	<u>Product(s)</u>	<u>Ref.</u>
2,6-(CH_3O) ₂ $C_6H_3OCH_3$	CH_3MgI	b. C_7H_8	ROH	1
2- CH_3O -5- $CH_3CH=CHC_6H_3OCH_2C_6H_5$	CH_3MgI^*	—	ROH	2
2- CH_3O -5- $CH_3CH=CHC_6H_3OCH_2CH=CH_2$	CH_3MgI^*	—	ROH	2
2- CH_3O -5- $CH_3CH=CHC_6H_3OCH(CH_2)_5$	CH_3MgI^*	—	ROH	2
2- CH_3O -5- $CH_3CH=CHC_6H_3O-i-C_3H_7$	CH_3MgI^*	—	ROH	2
3- $R'''O$ -4- $CH_3CH=CHC_6H_3OCH_3$ †	CH_3MgI	—	ROH	3
3- $n-C_3H_7$ -4- $CH_3CH=CHC_6H_3OCH_3$	CH_3MgI	—	ROH	3
3- C_2H_5 -4- $CH_3CH=CHC_6H_3OCH_3$	CH_3MgI	b. xylene (2 hrs.)	ROH	3
4- $CH_3OC_6H_4OCH_3$	$R''MgX$	200°	ROH	4, c/. 5
4- $CH_3OC_6H_4OCH_3$	$R''MgX$	—	ROH	4
4- $CH_3OC_6H_4OCH_2(\alpha-C_4H_3O)$ ‡	$n-C_4H_9MgCl$	b. C_6H_6	ROH (69%) + $R'R''$ (15%) + rearr. § (20%)	6
4- $C_2H_5OC_6H_4OCH_3$	$R''MgX$	200-230°	ROH	4
4- $C_2H_5OC_6H_4OCH_3$	$R''MgX$	—	ROH	4
4- $n-C_3H_7OC_6H_4OCH_3$	$R''MgX$	—	ROH	4
4- $n-C_4H_9OC_6H_4OCH_3$	$R''MgX$	—	ROH	4
4- $R'''SeC_6H_4OCH_3$ ¶	CH_3MgI	—	ROH (62-78%)¶	7
2- $C_6H_5OC_6H_4OC_2H_5$	$R''MgX$	—	ROH	8

* Similar, but "less satisfactory" results were obtained with C_2H_5MgBr .

† $R''' = "CH_2OC_2H_5, CH_2O-n-C_3H_7, \text{etc.}"$

‡ ($\alpha-C_4H_3O$) = 2-furyl.

§ The rearrangement product is 2- α -furylmethyl-4-methoxyphenol.

¶ $R''' = CH_3$ (78.2%); C_2H_5 (62.4%); $n-C_3H_7$ (76.0%); $i-C_3H_7$ (74.5%); $n-C_4H_9$ (76.0%); $i-C_4H_9$ (74.0%); $n-C_6H_{13}$ (74.0%).

TABLE XV-I (Continued)

<u>ROR'</u>	<u>R''MgX</u> (or <u>MgX₂</u>)	<u>Temp.</u> (<u>Time</u>)	<u>Product(s)</u>	<u>Ref.</u>
2-C ₆ H ₅ OC ₆ H ₄ O- <i>n</i> -C ₃ H ₇	R''MgX	—	ROH	8
2-CH ₃ OC ₆ H ₄ OCH ₃	CH ₃ MgI	160–170°	ROH (85%)	9
2-CH ₃ OC ₆ H ₄ OCH ₂ C ₆ H ₅	R''MgX	—	ROH	8
2-CH ₃ OC ₆ H ₄ OCH ₂ CH=CH ₂	<i>n</i> -C ₄ H ₉ MgBr	60° (14 hrs.)	ROH (87%) + R'R'' (36%)	10
2-CH ₃ OC ₆ H ₄ OCH ₂ (α -C ₄ H ₃ O) *	<i>n</i> -C ₄ H ₉ MgCl	b. C ₆ H ₆	ROH (74%) + R'R'' (63%) + rearr. † (14%)	6
2-C ₂ H ₅ OC ₆ H ₄ OCH ₃	R''MgX	—	ROH	8
2-C ₂ H ₅ OC ₆ H ₄ OC ₂ H ₅	R''MgX	—	ROH	8
2-C ₂ H ₅ OC ₆ H ₄ OCH ₂ C ₆ H ₅	R''MgX	—	ROH	8
2- <i>n</i> -C ₃ H ₇ OC ₆ H ₄ OCH ₃	R''MgX	—	ROH	8
2- <i>n</i> -C ₄ H ₉ OC ₆ H ₄ OCH ₃	R''MgX	—	ROH	8
2- <i>n</i> -C ₄ H ₉ OC ₆ H ₄ OC ₂ H ₅	R''MgX	—	ROH	8
2-HOC ₆ H ₄ OCH ₃	CH ₃ MgI	155–160° (2 hrs.)	ROH (+ ROR')	9
2-R'''SeC ₆ H ₄ OCH ₃ †	CH ₃ MgI	—	ROH (30–69%) †	7
4-CH ₃ CH=CHC ₆ H ₄ OCH ₃	C ₂ H ₅ MgI	—	ROH (+ polymer?)	11
4-CH ₃ CH=CHC ₆ H ₄ OCH ₃	<i>n</i> -C ₃ H ₇ MgI	—	ROH (+ polymer?)	11
4-H ₂ C=CHCH ₂ C ₆ H ₄ OCH ₃	CH ₃ MgI	160–170°	ROH (59%)	12, cf. 13
4-H ₂ C=CHCH ₂ C ₆ H ₄ OCH ₃	C ₂ H ₅ MgBr	—	ROH + gases	14, 13
4-H ₂ C=CHCH ₂ C ₆ H ₄ OC ₂ H ₅	C ₂ H ₅ MgI	—	ROH + gas	9
C ₆ H ₅ OC ₆ H ₅	C ₂ H ₅ MgI	170–190° (15 hrs.)	ROH (31%) + rearr. § (6.5%)	9
C ₆ H ₅ OCH ₃	CH ₃ MgBr	—	ROH + gases	13
C ₆ H ₅ OCH ₃	CH ₃ MgI	200–220° (8 hrs.)	ROH (85%) + "C ₂ H ₆ "	5, cf. 13
C ₆ H ₅ OCH ₃	MgBr ₂	200–220° (1 hr.)	ROH (<< 66%)	15
C ₆ H ₅ OCH ₃	MgI ₂	200–220° (1 hr.)	ROH (66%)	15, cf. 13

* (α -C₄H₃O) = 2-furyl.† The rearrangement product is 2-methoxy-6- α -furylmethylphenol.‡ R''' = CH₃ (65%); C₂H₅ (69%); *n*-C₃H₇ (49%); *i*-C₃H₇ (53%); *n*-C₄H₉ (63%); *i*-C₄H₉ (45%); *i*-C₅H₁₁ (50%); *n*-C₆H₁₃ (30%).

§ The rearrangement product is 2-biphenylol (2-phenylphenol).

TABLE XV-I (Continued)

<u>ROR'</u>	<u>R''MgX</u> (or MgX ₂)	<u>Temp.</u> (Time)	<u>Product(s)</u>	<u>Ref.</u>
C ₆ H ₅ OCH ₃	C ₂ H ₅ MgX	—	ROH + gases	13
C ₆ H ₅ OCH ₃	<i>i</i> -C ₃ H ₇ MgI	—	ROH + gases	13
C ₆ H ₅ OCH ₃	<i>n</i> -C ₄ H ₉ MgI	—	ROH + gases	13
C ₆ H ₅ OCH ₃	<i>i</i> -C ₅ H ₁₁ MgI	130–140°	ROH (78%) + RR'' (?)	9
C ₆ H ₅ OC ₂ H ₅	CH ₃ MgBr	—	ROH (16%) + gases + tar	13
C ₆ H ₅ OC ₂ H ₅	CH ₃ MgI	230° (1 hr.)	ROH (85%) + "C ₃ H ₈ "	5, <i>cf.</i> 13
C ₆ H ₅ OC ₂ H ₅	C ₂ H ₅ MgX	—	ROH + gases	13
C ₆ H ₅ OC ₂ H ₅	<i>n</i> -C ₄ H ₉ MgI	—	ROH + gases	13
C ₆ H ₅ OCH ₂ CH ₂ Br	C ₆ H ₅ CH ₂ MgCl	—	ROH + R''OH (?) * + C ₆ H ₅ O(CH ₂) ₃ C ₆ H ₅	16
C ₆ H ₅ OCH ₂ CH ₂ Br	<i>n</i> -C ₅ H ₁₁ MgBr	—	ROH + R''OH (?) *	16
C ₆ H ₅ OCH ₂ CH ₂ Br	C ₆ H ₅ MgBr	145°	C ₆ H ₅ OCH ₂ CH ₂ C ₆ H ₅	16
C ₆ H ₅ OCH ₂ C ₆ H ₅	MgBr ₂	b. Et ₂ O (46 hrs.)	"No change"	26
C ₆ H ₅ OCH ₂ C ₆ H ₅ (0.2 mole)	MgBr ₂	b. C ₆ H ₆ (24 hrs.)	Rec. ROR' (7.3 g.) + R'Br (5.0 g.) + ROH (12.0 g.) + h.-b. residue (15.0 g.)	26
C ₆ H ₅ OCH ₂ C ₆ H ₅	C ₂ H ₅ MgBr	170–190° (15 hrs.)	ROH (49%) + R'R'' (50%) + rec. ROR'	9
C ₆ H ₅ OCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr	80° (16 hrs.)	Rec. ROR' (91%)	10
C ₆ H ₅ OCH ₂ CH=CH ₂	MgBr ₂	95° (5 hrs.)	ROH (9%) + R'Br	15
C ₆ H ₅ OCH ₂ CH=CH ₂	<i>n</i> -C ₄ H ₉ MgCl	79° (5 hrs.)	ROH (74%)	10
C ₆ H ₅ OCH ₂ CH=CH ₂	<i>n</i> -C ₄ H ₉ MgBr	17° (3 hrs.)	ROH (<2%)	17
C ₆ H ₅ OCH ₂ CH=CH ₂	<i>n</i> -C ₄ H ₉ MgBr	17° (40 hrs.)	ROH (12%)	17
C ₆ H ₅ OCH ₂ CH=CH ₂	<i>n</i> -C ₄ H ₉ MgBr	17° (140 hrs.)	ROH (43%)	17
C ₆ H ₅ OCH ₂ CH=CH ₂	<i>n</i> -C ₄ H ₉ MgBr	34° (3 hrs.)	ROH (<2%)	17
C ₆ H ₅ OCH ₂ CH=CH ₂	<i>n</i> -C ₄ H ₉ MgBr	34° (40 hrs.)	ROH (61%)	17
C ₆ H ₅ OCH ₂ CH=CH ₂	<i>n</i> -C ₄ H ₉ MgBr	34° (140 hrs.)	ROH (58%)	17
C ₆ H ₅ OCH ₂ CH=CH ₂	<i>n</i> -C ₄ H ₉ MgBr	61–72° (4–6 hrs.)	ROH (51.0–86.5%) + R'R''	10
C ₆ H ₅ OCH ₂ CH=CH ₂	<i>n</i> -C ₄ H ₉ MgI	70–72° (5 hrs.)	ROH (53%)	10
C ₆ H ₅ OCH ₂ CH=CH ₂	<i>n</i> -C ₁₂ H ₂₅ MgBr	75° (6 hrs.)	ROH (71%) + R'R'' (43%)	10

* If this alcohol was indeed present among the reaction products, it must have arisen from oxygen contamination (see Chapter XX).

TABLE XV-I (Continued)

<u>ROR'</u>	<u>R'MgX</u> (or <u>MgX₂</u>)	<u>Temp.</u> (<u>Time</u>)	<u>Product(s)</u>	<u>Ref.</u>
C ₆ H ₅ OCH ₂ CH=CH ₂	C ₆ H ₅ MgBr	20° (210 hrs.)	ROH (63%)	17
C ₆ H ₅ OCH ₂ CH=CH ₂	C ₆ H ₅ MgBr	70° (7 hrs.)	ROH (71%) + R'R'' (63%)	10
C ₆ H ₅ OCH ₂ CH=CH ₂	C ₆ H ₅ MgI	70° (6 hrs.)	ROH (60%)	10
C ₆ H ₅ OCH ₂ CH=CH ₂	(C ₆ H ₅) ₂ Mg	75° (6 hrs.)	ROH (76%) + R'R'' (67%)	18
C ₆ H ₅ OCH ₂ (α -C ₄ H ₃ O) *	<i>n</i> -C ₄ H ₉ MgCl	b. C ₆ H ₆	ROH (60%) + R'R'' (46%) + rearr. [†] (31%)	6
C ₆ H ₅ OCH ₂ (α -C ₄ H ₃ O) *	<i>n</i> -C ₄ H ₉ MgBr	<i>c a.</i> 70° (<i>c a.</i> 5 hrs.)	ROH (40%) + R'R'' (31%) + rearr. [†] (44%)	6
C ₆ H ₅ OC(C ₆ H ₅) ₃	C ₆ H ₅ MgBr	b. Et ₂ O	(R'O—) ₂ (46%)	19
C ₆ H ₅ OC(C ₆ H ₅) ₃	C ₆ H ₅ MgBr	200°	R'R'' (15–20%) + R''H	19
CH ₃ OCH ₂ C ₆ H ₅	C ₆ H ₅ MgBr	170–180° (6 hrs.)	Rec. ROR' (62%) + R'R'' (14%)	9
CH ₃ OC(C ₆ H ₅) ₃	C ₆ H ₅ MgBr	200°	R'R'' (12%) + R''H	19
C ₂ H ₅ OCH ₂ C ₆ H ₅	CH ₃ MgBr	160–180° (8 hrs.)	R'R'' (39.6%) + R' ₂ O (11%)	9
C ₂ H ₅ OCH ₂ C ₆ H ₅	<i>n</i> -C ₃ H ₇ MgI	—	R'R'' + R' ₂	20
C ₂ H ₅ OCH(CH ₃)- <i>i</i> -C ₄ H ₉	CH ₃ MgI	170–190° (40 hrs.)	R'R'' (12.4%)	9
C ₂ H ₅ OCH(C ₆ H ₅) ₂	<i>n</i> -C ₃ H ₇ MgI	—	R'R'' + R' ₂	20
C ₂ H ₅ OC(C ₆ H ₅) ₃ (14.4 g.)	<i>n</i> -C ₃ H ₇ MgI	b. Et ₂ O (10 min.)	Rec. ROR' (1.5 g.) + R'H (7.0 g.)	27
C ₂ H ₅ OC(C ₆ H ₅) ₃	<i>i</i> -C ₄ H ₉ MgI	—	R'H	28
C ₂ H ₅ OC(C ₆ H ₅) ₃	C ₆ H ₅ MgBr	200°	R'R'' (8–12%) + RH	19
<i>n</i> -C ₃ H ₇ OCH(C ₆ H ₅) ₂	<i>n</i> -C ₃ H ₇ MgI	—	R' ₂ + gases	21,24
<i>n</i> -C ₃ H ₇ OCH(C ₆ H ₅) ₂	<i>i</i> -C ₄ H ₉ MgI	—	R' ₂	28
<i>n</i> -C ₄ H ₉ OCH(C ₆ H ₅) ₂	CH ₃ MgI	—	Rec. ROR' (42%) + R' ₂ (42%) + R''H (39%)	22,23
<i>n</i> -C ₄ H ₉ OCH(C ₆ H ₅) ₂	C ₂ H ₅ MgI	—	Rec. ROR' (50%) + R' ₂ (23%) + R'R'' (39%) + ROH (24%) + R''H (21%) + R''(-H)	22,23

* (α -C₄H₃O) = 2-furyl.[†]The rearrangement product is 2- α -furylmethylphenol.

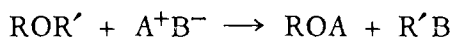
TABLE XV-I (Continued)

<u>ROR'</u>	<u>R'MgX (or MgX₂)</u>	<u>Temp. (Time)</u>	<u>Product(s)</u>	<u>Ref.</u>
<i>n</i> -C ₄ H ₉ OCH(C ₆ H ₅) ₂	<i>n</i> -C ₃ H ₇ MgI	—	Rec. ROR' (46%) + R' ₂ (24%) + R'OR'' (16%) + ROH (16%) + R''H (22%) + R''(-H) (5%)	23,24,25
<i>i</i> -C ₅ H ₁₁ O- <i>i</i> -C ₅ H ₁₁	CH ₃ MgI	200–215 ° (2.5 da.)	ROH (?)	9
<i>i</i> -C ₅ H ₁₁ OCH(C ₆ H ₅) ₂	<i>n</i> -C ₃ H ₇ MgI	—	Rec. ROR' + R''H	23
<i>n</i> -C ₈ H ₁₇ OCH ₂ CH=CH ₂	C ₆ H ₅ MgBr	75 ° (6 hrs.)	ROH (70.5%) + R'R'' (85.0%)	18
C ₆ H ₅ CH ₂ OCH ₂ C ₆ H ₅	CH ₃ MgI	160–170 ° (12 hrs.)	ROH (60%) + R'R'' (55%)	9

REFERENCES FOR TABLE XV-I

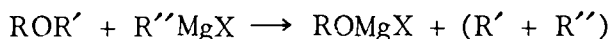
- (1) Hurd and Winberg, *J. Am. Chem. Soc.*, 64, 2085-6 (1942).
- (2) Hirao, *J. Chem. Soc. Japan*, 54, 991-5 (1933); *Chem. Abstr.*, 28, 471 (1934).
- (3) Hirao, *J. Chem. Soc. Japan*, 52, 263-9 (1931); *Chem. Abstr.*, 26, 5084 (1932).
- (4) Hirao, *J. Chem. Soc. Japan*, 54, 97-102 (1933); *Chem. Abstr.*, 27, 2944 (1933).
- (5) Simonis and Remmert, *Ber.*, 47, 269-71 (1914).
- (6) Normant, *Bull. soc. chim.*, [5], 7, 371-4 (1940).
- (7) Keimatsu, Yokata, and Satoda, *J. Pharm. Soc. Japan*, 53, 994-1046 (1933); *Chem. Abstr.*, 29, 7300 (1935).
- (8) Hirao, *J. Chem. Soc., Japan*, 53, 488-96 (1932); *Chem. Abstr.*, 27, 276 (1933).
- (9) Späth, *Monatsh.*, 35, 319-32 (1914).
- (10) Lüttringhaus, von Sääf, and Hauschild, *Ber.*, 71B, 1673-81 (1938).
- (11) Serini and Steinruck, *Naturwiss.*, 25, 682-3 (1937); *Chem. Abstr.*, 32, 2953 (1938).
- (12) Zemplin and Gerecs, *Ber.*, 70B, 1098-101 (1937).
- (13) Grignard and Ritz, *Bull. soc. chim.*, [5], 3, 1181-4 (1936).
- (14) Grignard, *Compt. rend.*, 151, 322-5 (1910); *Chem. Zentr.*, 1910,II, 1048.
- (15) Schönberg and Moubasher, *J. Chem. Soc.*, 1944, 462-3.
- (16) Grignard, *Compt. rend.*, 138, 1048-50 (1904); *Chem. Zentr.*, 1904,I, 1493.
- (17) Lüttringhaus and von Sääf, *Angew. Chem.*, 51, 915-20 (1938).
- (18) Lüttringhaus, Wagner-von Sääf, Sucker, and Borth, *Ann.*, 557, 46-69 (1945).
- (19) Gomberg and Kamm, *J. Am. Chem. Soc.*, 39, 2009-15 (1917).
- (20) Tschelinzew and Pawlow, *J. Russ. Phys.-Chem. Soc.*, 45, 289-300 (1913); *Chem. Zentr.*, 1913,I, 1962; *Chem. Abstr.*, 7, 2227 (1913).
- (21) Stadnikow, *J. Russ. Phys.-Chem. Soc.*, 44, 1219-47 (1912); *Chem. Zentr.*, 1913,I, 21.
- (22) Stadnikow, *J. Russ. Phys.-Chem. Soc.*, 45, 1391-44 (1913); *Chem. Zentr.*, 1913,II, 2120.
- (23) Stadnikoff, *Ber.*, 46, 2496-503 (1913).
- (24) Stadnikoff, *J. prakt. Chem.*, [2], 88, 1-20 (1913).
- (25) Stadnikoff and Kusmina-Aron, *J. prakt. Chem.*, [2], 88, 20-5 (1913).
- (26) Gilman and Schulze, *Rec. trav. chim.*, 47, 752-60 (1928).
- (27) Stadnikoff, *Ber.*, 44, 1157-60 (1911).
- (28) Stadnikow, *J. Russ. Phys.-Chem. Soc.*, 43, 1244-57 (1911); *Chem. Abstr.*, 6, 1434 (1912).

Speculations on the mechanism of ether cleavage. If, for the moment, the Schönberg and Moubasher hypothesis be set aside, and it be presumed tentatively that ether cleavage is, in general, effected by the Grignard reagent itself, then it may be stated empirically that the direction of cleavage of an unsymmetrical ether follows the general rule for the cleavage of unsymmetrical ethers by polar reagents. This is most economically stated in the form of an equation in which R represents a radical more "electronegative"¹⁷ than R', and A is the positive and B the negative constituent of the polar reagent:

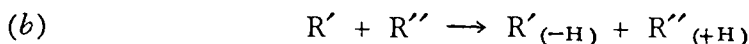


¹⁷For a discussion of the relative "electronegativities" of organic radicals see: Kharasch and Reinmuth, *J. Chem. Education*, 5, 404-18 (1928); 8, 1703-48 (1931); Kharasch, Reinmuth, and Mayo, *ibid.*, 11, 82-96 (1934); 13, 7-19 (1936).

For the special case of the Grignard reagent ($R''MgX$) the rule may be stated more specifically:

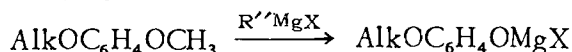


The product resulting from the interaction of R' with R'' depends upon the natures of the specific radicals (or, rather, ions) involved:



As a subsidiary rule it may be stated that when R is very strongly "electronegative" and R' is very weakly "electronegative" the ether is much more susceptible to cleavage than when both R and R' are strongly or even moderately "electronegative."

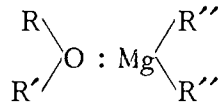
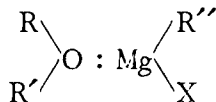
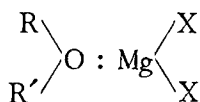
What might at first glance appear to constitute a minor inconsistency with the general spirit of the stated rules crops up in the cleavages of the methyl alkyl ethers of the diphenols. Invariably the methyl group (the most "electronegative" of the alkyl groups) is removed in preference to the other alkyl group,¹⁸ e.g.,



However, this inconsistency may be more apparent than real. There is some reason to believe that a hydroxyphenyl group is markedly more "electronegative" than a methoxyphenyl group. Whereas the hydrogen atom is considerably less "electronegative" than any of the alkyl groups, it would seem to follow that the alkoxyphenyl groups in general are intermediate in "electronegativity" between the hydroxyphenyl and the methoxyphenyl groups. It may be, therefore, that in general the $AlkOC_6H_4O-CH_3$ bonds are more polar (and hence more susceptible to cleavage) than the $CH_3OC_6H_4O-Alk$ bonds.

In view of the relatively low rates of ether cleavage by Grignard reagents there would appear to be no reason why satisfactory kinetic studies could not be made directly with intelligently selected reactant pairs. To the knowledge of the present authors, however, no such studies have as yet been made. Present speculations on mechanism must, therefore, be based on *a priori* reasoning and extension by analogy of what is known about other polar ether cleavages.

The known properties of ethereal Grignard reagent solutions (see Chapter IV) make it seem a reasonable assumption that the inevitable prelude to ether-Grignard reagent reaction is the formation of Werner complexes of one or more of the following types:

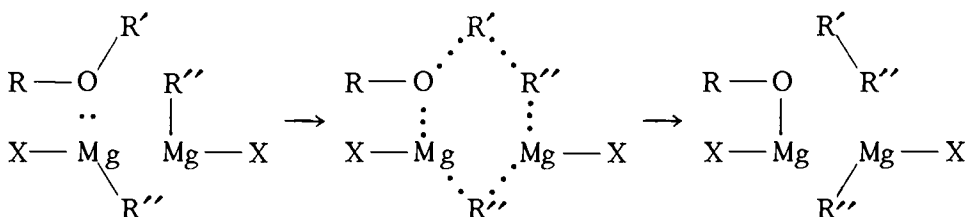


¹⁸Hirao, *J. Chem. Soc. Japan*, 52, 263-9 (1931); 54, 97-102, 991-5 (1933); *Chem. Abstr.*, 26, 5084 (1932); 27, 2944 (1933); 28, 471 (1934); *Bull. Chem. Soc. Japan*, 11, 179-84 (1936); *Chem. Abstr.*, 30, 5953 (1936).

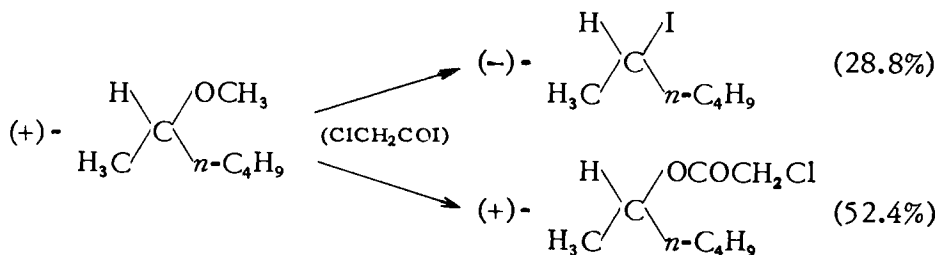
Under suitably selected experimental conditions kinetic studies could determine whether cleavage takes place through thermal rearrangement of such a complex or through attack of a second molecule of one of the Grignard reagent components upon the complex.

In view of the relative stability of most ethereal carbon-to-oxygen bonds, one would be inclined to regard favorably the latter possibility as affording opportunity for a concerted "push-pull" mechanism which would presumably have a relatively low energy of activation. Kinetic studies of the supposedly analogous hydrogen bromide cleavage of ethyl ether by Mayo *et al.*¹⁹ reveal that in toluene or chlorobenzene (and presumably in excess ethyl ether) the reaction is third-order (*i.e.*, first-order with respect to ether, and second-order with respect to hydrogen bromide).

A mechanism consistent with similar kinetics for the Grignard reagent cleavage could be formulated in terms of the familiar quasi six-membered ring transition state.



There would seem to be no compelling reason to adopt the six-membered ring transition state for the particular type of cleavage illustrated. However, any concerted "push-pull" mechanism would imply a Walden inversion of the oxygen-linked carbon atom of R'. Such inversion has not been demonstrated for any Grignard ether cleavage, but has been shown to occur in that portion of the chloroacetyl iodide cleavage of (+)-*s*-hexyl methyl ether that leads to the production of 2-iodohexane (Stevens²⁰).

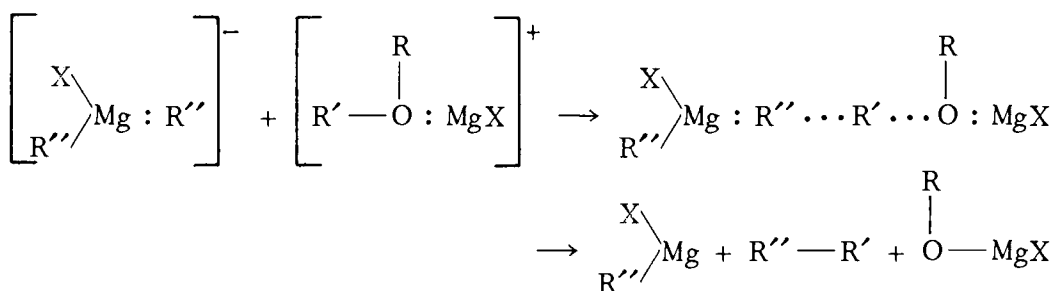


(More precisely, it has been demonstrated that there is a retention of optical activity with presumable inversion.)

In the more general convention commonly employed the postulated mechanism might be formulated as follows:

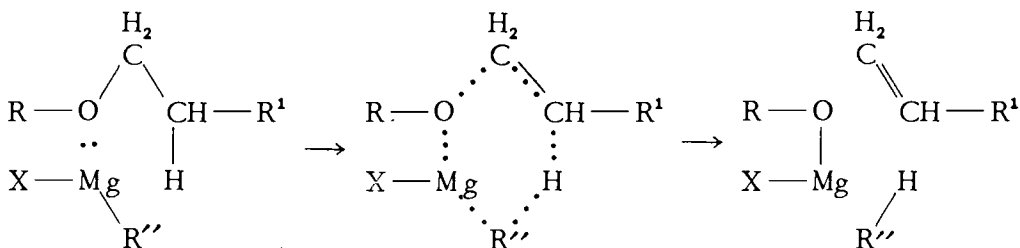
¹⁹Mayo, Hardy, and Schultz, *J. Am. Chem. Soc.*, 63, 426-36 (1941). Concerning the hydrogen bromide cleavage of optically active methyl *s*-butyl ether, see: Burwell, Elkin, and Maury, *J. Am. Chem. Soc.*, 73, 2428-31 (1951).

²⁰Stevens, *J. Am. Chem. Soc.*, 62, 1801-2 (1940).

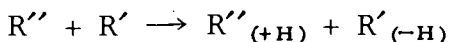


Obviously the magnesium halide cleavages might be formulated in either of the ways suggested.

As regards the cleavages in which R' and R'' disproportionate rather than combine, however, a special significance might attach to the six-membered ring method of formulation. Conceivably, such cleavages could be bimolecular. By way of illustration (with $\text{R}' = \text{R}^1\text{CH}_2\text{CH}_2$):

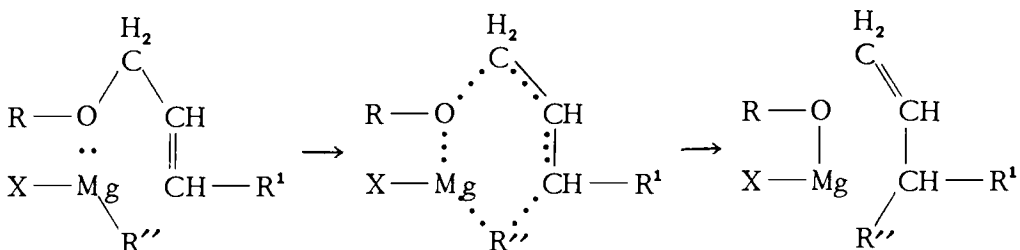


Under suitable experimental conditions such a reaction would, of course, display second-order kinetics, and the disproportionation would be strictly a one-way affair.



Unfortunately, the data presently available can scarcely be accepted as constituting sufficient grounds for either acceptance or rejection of this formulation.

With the allylic ethers also, there is the possibility of a bimolecular reaction.



It is altogether possible that allylic ethers undergo both bimolecular and trimolecular cleavages.

REDUCTIVE (FREE-RADICAL) CLEAVAGE OF ETHERS

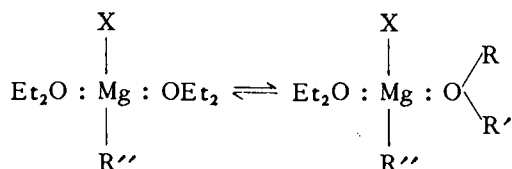
Although nothing in the presently available data appears to prohibit treatment of the Grignard reagent cleavages of ethers as special cases of solvolysis in which the Grignard reagent plays the rôle of a polar

"solvent," there are certain aspects of the *res gestae* which tend to raise the question whether these reactions may not, in part at least, involve free-radical processes. (1) In general, these reactions proceed very slowly (if at all) at the boiling point of ethyl ether;* usually they are conducted in the temperature range 160–200°. (2) It has been reported by, *inter alios*, Grignard and Ritz²¹ that the organomagnesium iodides are more effective ether-cleavage reagents than the corresponding bromides or chlorides. (3) Stadnikoff (*loc. cit.*³) found considerable quantities of symmetrical tetraphenylethane (bibenzhydryl) among the products of Grignard reagent cleavages of benzhydryl ethers—unmistakable evidence of a free-radical process of some sort (though not necessarily one directly associated with the ether-cleavage stage of the reaction).

For these reasons Kharasch and Huang²² undertook to investigate the effect upon the cleavage reaction of an experimental device known to produce free radicals from Grignard reagents at relatively low temperatures, namely, the addition to the reaction system of certain metallic halides, notably cobaltous chloride.

The procedure adopted was to add the metallic halide in small portions at intervals over a period of three to four hours to an ethyl ether solution of the Grignard reagent containing the ether under investigation. After the addition had been completed the reaction mixture was heated for about thirty minutes to the boiling point of ethyl ether and was then allowed to cool. Under the experimental conditions described neither the Grignard reagents nor any of the metallic halides tested (save aluminum chloride) effected appreciable cleavage of any of the ethers investigated. The results of the combined action of Grignard reagents and metallic halides on ethers are summarized in Table XV-II. In many respects they are strikingly similar to those observed in the hydrogenolysis of ethers in the presence of Raney nickel.²³

*This may not be altogether a temperature effect. Ethyl ether (one of the more basic ethers) would probably be a very poor solvent for ether cleavage studies even at high temperatures under pressure. The equilibrium



would probably tend, in most cases, to lie far toward the left, especially if ethyl ether were present in excess. [Concerning the solvent effect in Grignard reactions, *cf.*: Lewis and Wright, *J. Am. Chem. Soc.*, 74, 1253–7 (1952).]

²¹ Grignard and Ritz, *Bull. soc. chim.*, [5], 3, 1181–4 (1936).

²² Kharasch and Huang, *J. Org. Chem.*, 17, 669–77. (1952).

²³ Adkins, "Reactions of Hydrogen with Organic Compounds with Copper-Chromic Oxide and Nickel Catalysts," The University of Wisconsin Press, Madison, Wis., 1937, pp. 73–5.

TABLE XV-II

REACTIONS OF ETHERS (1 MOLE) WITH ETHYL ETHEREAL GRIGNARD REAGENT SOLUTIONS
IN THE PRESENCE OF METALLIC HALIDES AT OR NEAR ROOM TEMPERATURE

ROR' (1 Mole)	R''MgX (Moles)	Halide (Moles)	% Cleavage *
4-CH ₃ OC ₆ H ₄ OC ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (6)	CoCl ₂ (2.5)	33 [†]
4-CH ₃ OC ₆ H ₄ O- <i>i</i> -C ₃ H ₇	<i>n</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	0
4-CH ₃ OC ₆ H ₄ OCH ₂ C ₆ H ₅	<i>i</i> -C ₃ H ₇ MgBr (4)	CoCl ₂ (2.0)	82
4-CH ₃ OC ₆ H ₄ OCH ₂ C ₆ H ₅	C ₆ H ₅ MgBr (4)	CoCl ₂ (2.0)	10
1-C ₁₀ H ₇ OC ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (6)	CoCl ₂ (2.5)	52 [‡]
1-C ₁₀ H ₇ OC ₂ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	0
1-C ₁₀ H ₇ OCH ₂ C ₆ H ₅	CH ₃ MgBr (4)	CoCl ₂ (2.0)	31
1-C ₁₀ H ₇ OCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (2)	CoCl ₂ (1.1)	40
1-C ₁₀ H ₇ OCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	81
2-C ₁₀ H ₇ OCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (2)	CoCl ₂ (1.1)	35
C ₆ H ₅ OC ₆ H ₅	C ₂ H ₅ MgBr (4)	CoCl ₂ (2.0)	42
C ₆ H ₅ OC ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	43
C ₆ H ₅ OC ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (6)	CoCl ₂ (2.5)	72
C ₆ H ₅ OC ₆ H ₅	<i>t</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	58
C ₆ H ₅ OCH ₃	<i>n</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	0
C ₆ H ₅ OC ₂ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	0
C ₆ H ₅ O- <i>i</i> -C ₃ H ₇	<i>n</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	5
C ₆ H ₅ OCH ₂ CH=CH ₂	<i>n</i> -C ₄ H ₉ MgBr (1.2)	CoCl ₂ (0.01)	89
C ₆ H ₅ OCH ₂ C ₆ H ₅	C ₆ H ₅ MgBr (4)	CoCl ₂ (2.0)	<8 [§]
C ₆ H ₅ OCH ₂ C ₆ H ₅	CH ₃ MgBr (4)	CoCl ₂ (2.0)	35
C ₆ H ₅ OCH ₂ C ₆ H ₅	C ₂ H ₅ MgBr (2)	CoCl ₂ (0.3)	9
C ₆ H ₅ OCH ₂ C ₆ H ₅	C ₂ H ₅ MgBr (2)	CoCl ₂ (2.0)	18

* Except where otherwise noted the phenolic (or alcoholic) product is ROH.

[†] The phenolic product is chiefly phenol.

[‡] The phenolic product is 36% phenol, 16% 1-naphthol.

[§] After correction for phenol formed by oxygenation of the Grignard reagent.

TABLE XV-II (Continued)

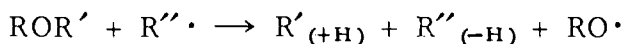
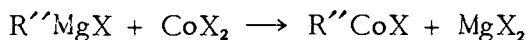
<u>ROR' (1 Mole)</u>	<u>R''MgX (Moles)</u>	<u>Halide (Moles)</u>	<u>% Cleavage *</u>
C ₆ H ₅ OCH ₂ C ₆ H ₅	C ₂ H ₅ MgBr (4)	CoCl ₂ (2.0)	48
C ₆ H ₅ OCH ₂ C ₆ H ₅	C ₂ H ₅ MgBr (2)	FeCl ₃ (0.3)	8
C ₆ H ₅ OCH ₂ C ₆ H ₅	<i>i</i> -C ₃ H ₇ MgBr (4)	CoCl ₂ (2.0)	80
C ₆ H ₅ OCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	86
C ₆ H ₅ OCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	NiCl ₂ (2.0)	68
C ₆ H ₅ OCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	FeCl ₃ (2.0)	65
C ₆ H ₅ OCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	CuCl ₂ (2.0)	10
C ₆ H ₅ OCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	Cu ₂ Br ₂ (2.0)	0
C ₆ H ₅ OCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	MnCl ₂ (2.0)	0
C ₆ H ₅ OCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	AlCl ₃ (2.0)	3 [†]
C ₆ H ₅ OCH ₂ C ₆ H ₅	<i>s</i> -C ₄ H ₉ MgBr (2)	CoCl ₂ (1.0)	66
C ₆ H ₅ OCH ₂ C ₆ H ₅	<i>s</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	82
C ₆ H ₅ OCH ₂ C ₆ H ₅	<i>t</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	92
C ₆ H ₅ OCH ₂ CH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	49
CH ₃ OCH ₂ C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	90
(C ₆ H ₅ CH ₂) ₂ O	<i>n</i> -C ₄ H ₉ MgBr (4)	CoCl ₂ (2.0)	88

* Except where otherwise noted the phenolic (or alcoholic) product is ROH.

[†] Under the experimental conditions here employed, aluminum chloride in the absence of a Grignard reagent effects *ca.* 25% ether cleavage.

Under the experimental conditions described alkyl benzyl, aryl benzyl, aryl allyl, and diaryl ethers undergo cleavage in ethyl ether solution at room temperature. Although phenyl phenethyl ether may be regarded as an exception, the phenyl alkyl ethers in general do not undergo cleavage under these conditions; it may be, however, that they are otherwise hydrogenated. Isosafrole is converted principally to dihydrosafrole, with very little opening of the methylenedioxy ring.

The products of the cleavage of phenyl benzyl ether are phenol and toluene; those of phenyl allyl ether, phenol and propylene. In general it would appear that such cleavages are reductive, with the free radical of the Grignard reagent supplying the reducing hydrogen atom. The data at hand do not justify the formulation of a detailed reaction mechanism, but the essential features of the processes involved may be indicated by some such scheme as the following:



Insofar as methyl or phenyl Grignard reagents are effective in bringing about such cleavages, they probably operate indirectly by attacking the ethyl ether present, with the production of ethyl radicals. The gases from the methylmagnesium bromide cleavage of phenyl benzyl ether include methane, ethylene, and ethane.

It would appear, therefore, that most of the Grignard reagent cleavages of ethers hitherto reported are probably ionic "solvolysis" reactions, rather than free-radical processes.

PREPARATIVE PROCEDURES

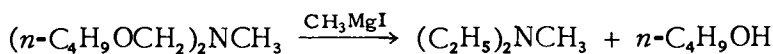
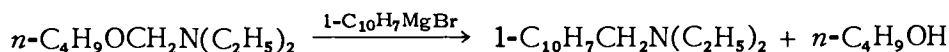
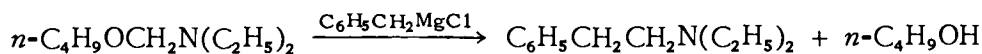
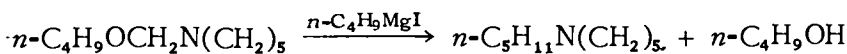
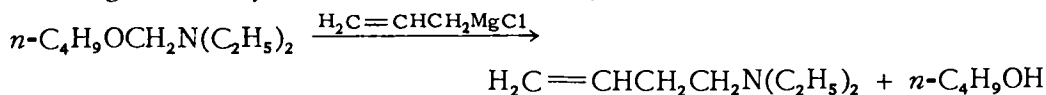
With a few exceptions, such as Gomberg's (*loc. cit.*¹³) preparation of tetraphenylmethane, the Grignard cleavages of ethers have found preparative use chiefly in the dealkylation (usually demethylation) of "protected" aromatic hydroxyl groups which for one reason or another do not lend themselves to satisfactory treatment with hydrogen iodide, hydrogen bromide, or concentrated alkali. Incidentally, for some reason not altogether obvious, the aromatic benzyl ethers seem to offer little or no special advantages, being nearly as stable toward Grignard reagents as the corresponding methyl ethers. A common procedure is to add the ether to be dealkylated to an excess of an ethyl ethereal solution of methylmagnesium iodide, to remove the ethyl ether by distillation, and then to bring the reaction mixture to the desired temperature (usually 160–200°) by means of an oil-bath for the required length of time (often only until the desired bath temperature is reached; sometimes four to six hours).

Among those who have made use of the Grignard cleavage in the preparation of synthetic estrogens are: Zajic and Wesseley,²⁴ Linnell and

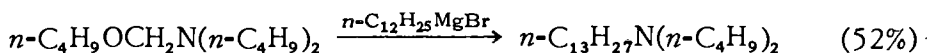
²⁴Zajic and Wesseley, German Patent 701,402, Dec. 12, 1944; *Chem. Abstr.*, 35, P7661 (1941).

Shaikmahamud,²⁵ Hobday and Short,²⁶ Menzer and Urbain,²⁷ Hudson,^{28,29} Wilds and McCormack,³⁰ Wessely and Prillinger,³¹ Sisido and Nozaki,³² Ungnade and Tucker,³³ and Mousseron and Winternitz.³⁴

A reaction which would appear to have some preparative potentialities, although yields are not stated, is described by Robinson and Robinson.³⁵ This consists in the cleavage of dialkylaminomethyl *n*-butyl ethers by Grignard reagents. The reaction is said to take place vigorously when an ethereal Grignard reagent solution is added dropwise to an ethereal dialkylamino ether solution. (The amino ethers are prepared by condensing secondary amines with formaldehyde and *n*-butyl alcohol.)

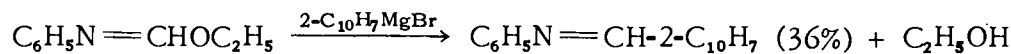
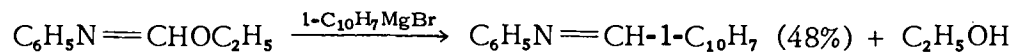
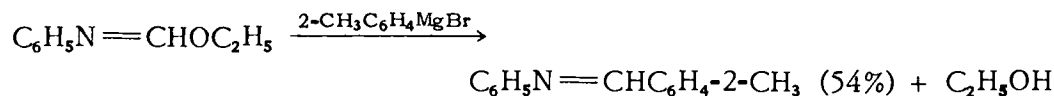
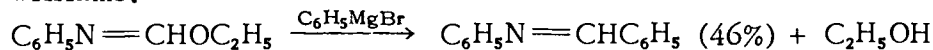


Apparently little use has been made of this reaction, though an additional example is reported by Massie.³⁶



It is probable that the reaction mechanism of this cleavage differs somewhat from that of the cleavages previously discussed.

Somewhat similar imino ether cleavages have been reported by Monier-Williams.^{36.1}



²⁵ Linnell and Shaikmahamud, *Quart. J. Pharm. Pharmacol.*, 15, 384-8 (1942).

²⁶ Hobday and Short, *J. Chem. Soc.*, 1943, 609-12.

²⁷ Menzer and Urbain, *Compt. rend.*, 215, 554-6 (1942); *Bull. soc. chim.*, [5], 10, 353-6 (1943); *Chem. Abstr.*, 38, 2645 (1944).

²⁸ Hudson and Walton, *J. Chem. Soc.*, 1946, 85-7.

²⁹ Hudson, *J. Chem. Soc.*, 1946, 754-5.

³⁰ Wilds and McCormack, *J. Am. Chem. Soc.*, 70, 884-5, 4127-32 (1948).

³¹ Wessely and Prillinger, *Ber.*, 72B, 629-33 (1939).

³² Sisido and Nozaki, *J. Am. Chem. Soc.*, 70, 776-8 (1948).

³³ Ungnade and Tucker, *J. Am. Chem. Soc.*, 71, 2584-5 (1949).

³⁴ Mousseron and Winternitz, *Bull. soc. chim.*, [5], 15, 567-70 (1948).

³⁵ Robinson and Robinson, *J. Chem. Soc.*, 123, 532-43 (1923).

³⁶ Massie, *Iowa State Coll. J. Sci.*, 21, 41-5 (1946); *Chem. Abstr.*, 41, 3043 (1947).

^{36.1} Monier-Williams, *J. Chem. Soc.*, 89, 273-80 (1906).

CLEAVAGES OF CYCLIC ETHERS

Whereas the "normal" reaction of a Grignard reagent with an epoxide may be regarded as constituting a special case of ether cleavage, these reactions present so many unique features that they have been discussed separately (see Chapter XIV).

Derick and Bissell³⁷ removed the ether from an ethereal mixture of *n*-propylmagnesium bromide and trimethylene oxide, and, upon further heating, observed a violent reaction. From the residue only traces of 1-hexanol could be isolated. When, however, the ether was partially replaced by benzene and the resultant mixture was refluxed at 70° for four hours, 1-hexanol was obtained in 43 percent yield.

Noller and Adams³⁸ refluxed an ethereal mixture of cyclopentylmagnesium bromide and trimethylene oxide for four hours, partially replaced the ether by benzene, and continued the reflux at 70° for three hours. They obtained a very poor yield of 3-cyclopentyl-1-propanol (3 g., 0.023 mole alcohol from 29 g., 0.5 mole oxide).

Upon combining trimethylene oxide with an ethereal solution of ethylmagnesium bromide and allowing the system to stand overnight, Bermejo and Aranda³⁹ obtained a precipitate. The precipitate was warmed on a water-bath at 80° for a half-hour, and the residue was hydrolyzed. The products were 1-pentanol (30 percent) and trimethylene bromohydrin (34 percent).

More recently, Searles⁴⁰ has investigated the general applicability of the preparation of alcohols by treatment of trimethylene oxide with Grignard reagents and organolithium compounds. In general, the procedure employed was to add, with stirring, a solution of trimethylene oxide in three volumes of anhydrous ethyl ether to a cold ethereal solution of the Grignard reagent or organolithium compound. After an initial mildly exothermic reaction, during which a white precipitate generally separated, the mixture was refluxed for one hour. Benzene (150–200 ml.) was then added; the ether was removed by distillation through a Vigreux column; and the mixture was refluxed four hours, after which it was cooled and hydrolyzed with saturated ammonium chloride solution.

The procedure was modified for the reactions of the cyclohexyl, isopropyl, and *t*-butyl Grignard reagents and of anhydrous magnesium bromide in that the reaction mixture was allowed to stand at room temperature under an atmosphere of nitrogen for twenty-four hours before benzene was added, and the benzene mixture was refluxed only two hours after removal of ether. The results of the Grignard reactions are summarized in Table XV-III.

³⁷Derick and Bissell, *J. Am. Chem. Soc.*, 38, 2484 (1916).

³⁸Noller and Adams, *J. Am. Chem. Soc.*, 48, 1080–9 (1926).

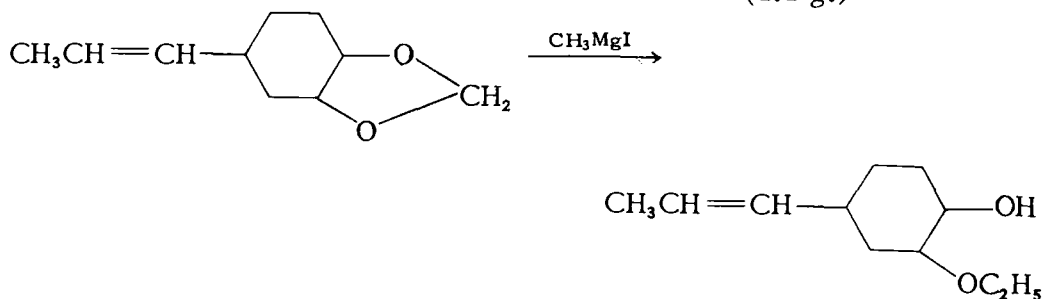
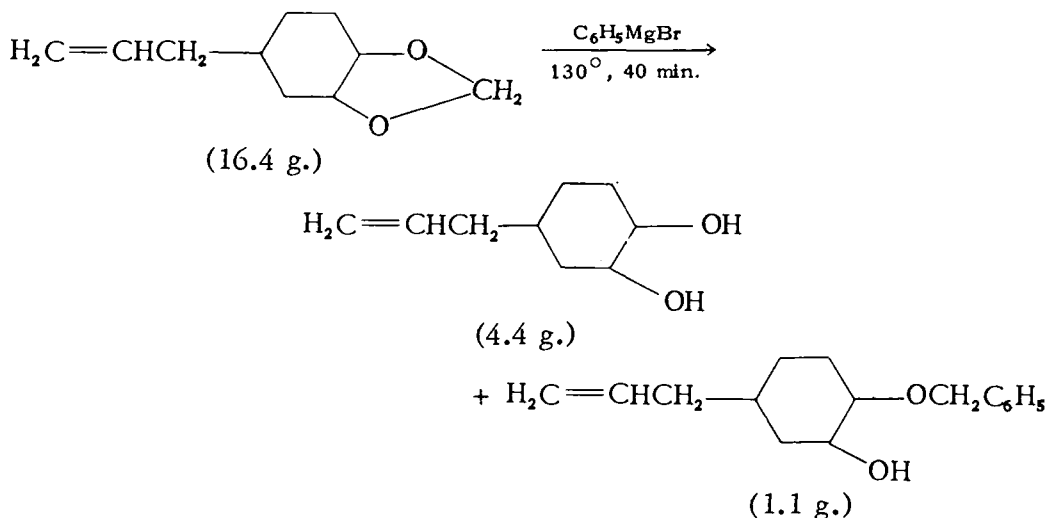
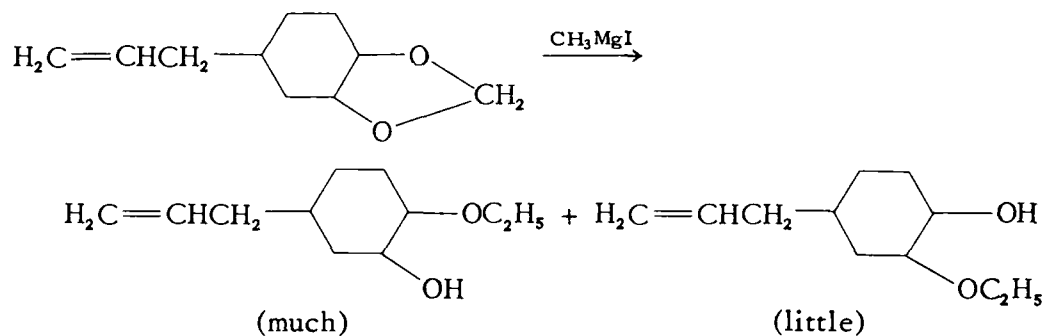
³⁹Bermejo and Aranda, *Anales soc. españ. fís. quim.*, 27, 798–800 (1929); *Chem. Zentr.*, 1930, I, 2382.

⁴⁰Searles, *J. Am. Chem. Soc.*, 73, 124–5 (1951).

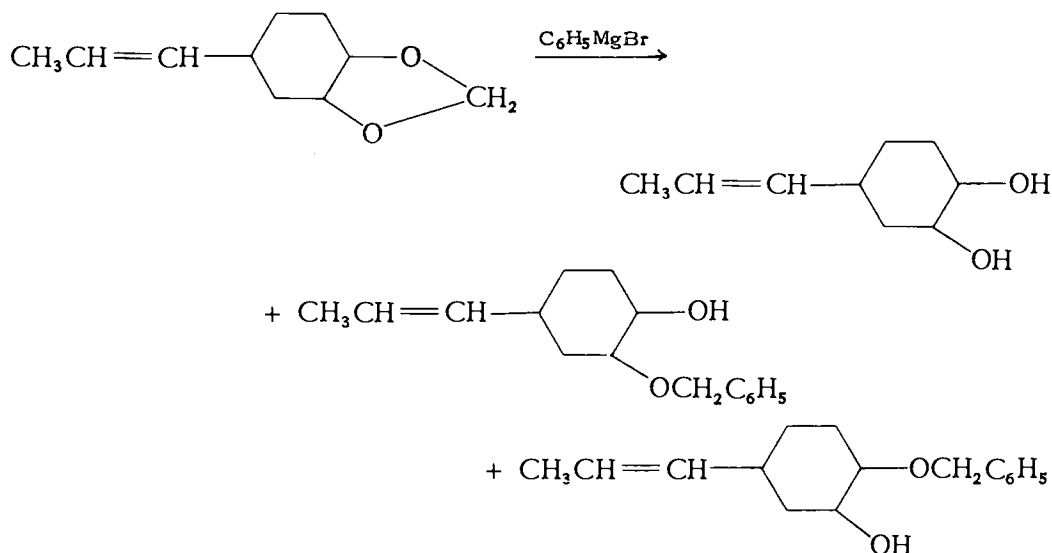
TABLE XV-III
REACTIONS OF SOME GRIGNARD REAGENTS WITH
TRIMETHYLENE OXIDE

RMgX (Mole)	Mole (CH ₂) ₃ O	Product(s)
<i>i</i> -C ₃ H ₇ MgBr (0.25)	0.20	<i>i</i> -C ₃ H ₇ (CH ₂) ₃ OH (28%); Br(CH ₂) ₃ OH (12%)
<i>t</i> -C ₄ H ₉ MgCl (0.25)	0.18	<i>t</i> -C ₄ H ₉ (CH ₂) ₃ OH (?); Cl(CH ₂) ₃ OH (37%)
C ₆ H ₅ MgBr (0.20)	0.18	C ₆ H ₅ (CH ₂) ₃ OH (84%); Br(CH ₂) ₃ OH (4%)
(CH ₂) ₅ CHMgBr (0.30)	0.20	(CH ₂) ₅ CH(CH ₂) ₃ OH (28%); Br(CH ₂) ₃ OH (40%)
C ₆ H ₅ CH ₂ MgCl (0.20)	0.13	C ₆ H ₅ (CH ₂) ₄ OH (83%)
1-C ₁₀ H ₇ MgBr (0.30)	0.18	1-C ₁₀ H ₇ (CH ₂) ₃ OH (80%)
2-C ₁₀ H ₇ MgBr (0.18)	0.18	2-C ₁₀ H ₇ (CH ₂) ₃ OH (60%)

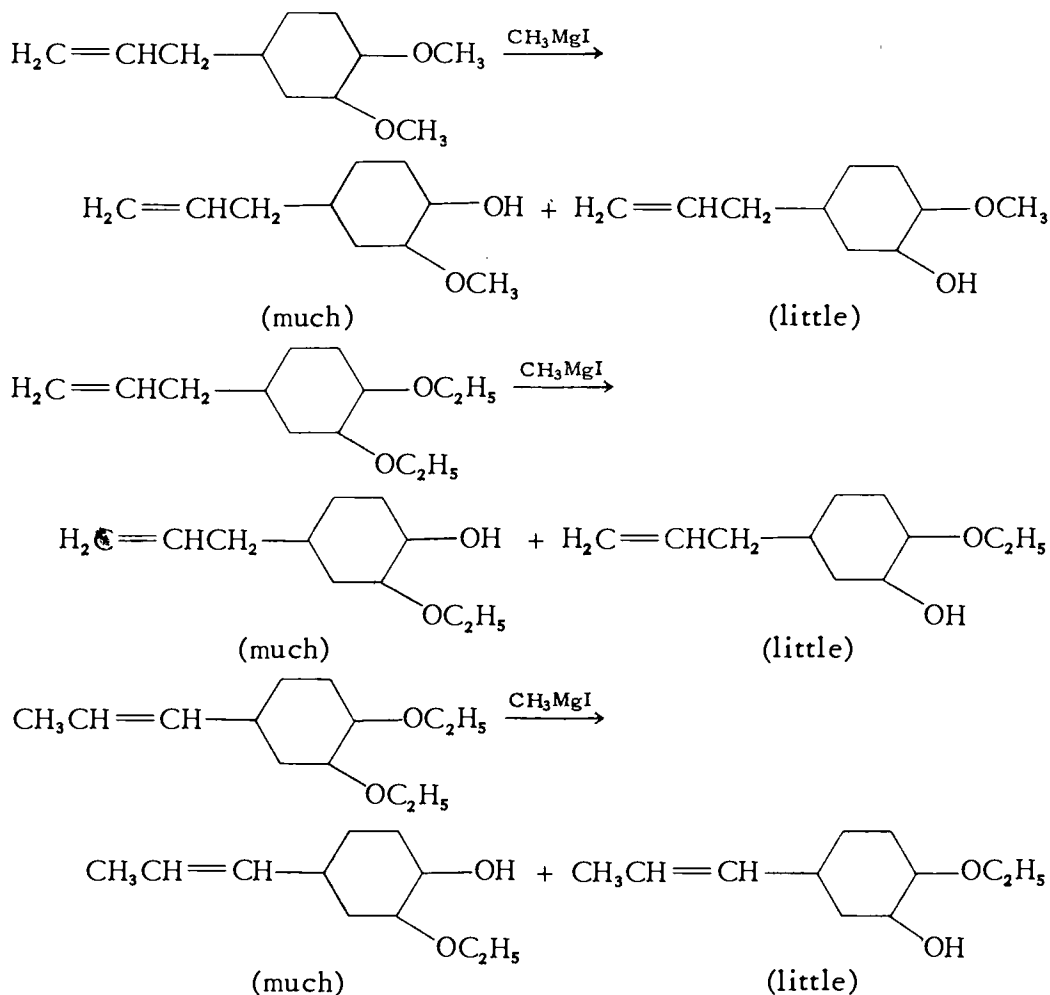
Hirao⁴¹ has reported Grignard cleavage of the methylenedioxy rings of safrole and isosafrole.



⁴¹Hirao, *J. Chem. Soc. Japan*, 52, 153-4, 525-8 (1931); 54, 499-504, 505-9 (1933); *Chem. Abstr.*, 25, 5156 (1931); 26, 5058 (1932); 27, 5730, 5731 (1933).



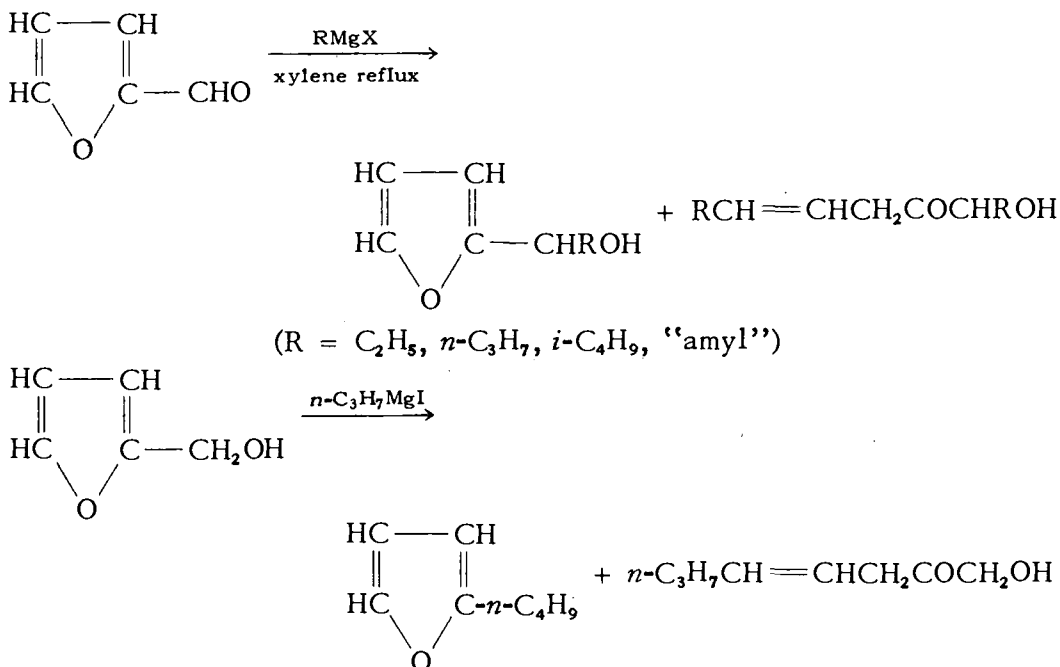
In the absence of more detailed experimental data one can scarcely draw any valid conclusions on the preferred direction of ring opening. According to Hirao,⁴² however, the corresponding dimethyl and diethyl ethers yield a preponderance of the *p*-hydroxy compounds.



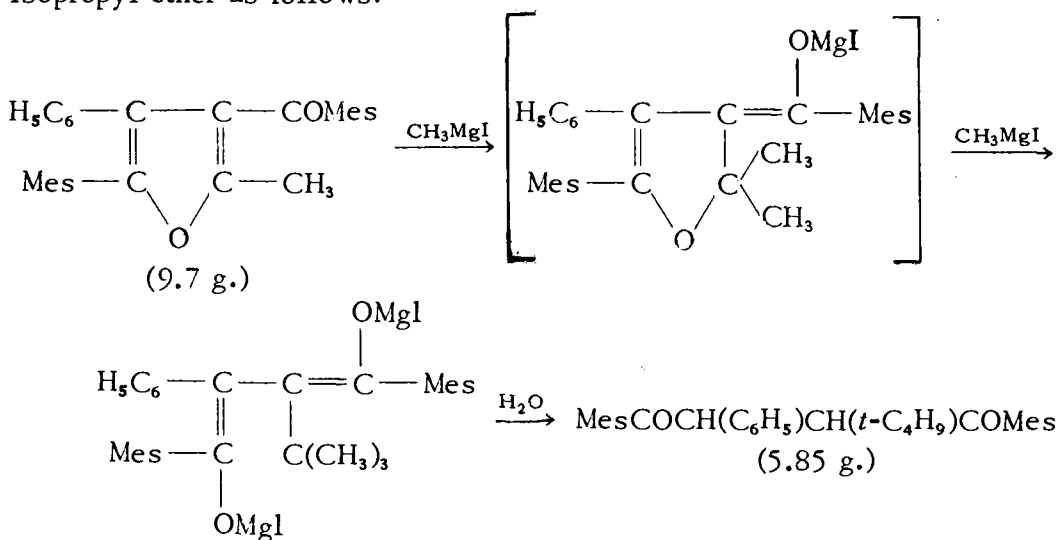
⁴²Hirao, *J. Chem. Soc., Japan*, 52, 519-24, 525-8 (1931); *Chem. Abstr.*, 26, 5085 (1932).

The opening of a tetramethylene oxide ring has been reported by Paul⁴³ who refluxed an ethereal Grignard solution prepared from 100 g. of α -bromomethyltetrahydrofuran for five hours and isolated 26 g. of 4-penten-1-ol.

Cleavages of the furan ring have been observed by Kuznetsov.⁴⁴



Lutz and Reveley⁴⁵ have observed similar cleavages, accompanied by 1,4-addition to a "hindered" α,β -unsaturated ketone. They formulate the reaction of 2-methyl-3-mesityl-4-phenyl-5-mesitylfuran with methylmagnesium iodide (5 equiv.) upon two and three-tenths hours reflux in isopropyl ether as follows:

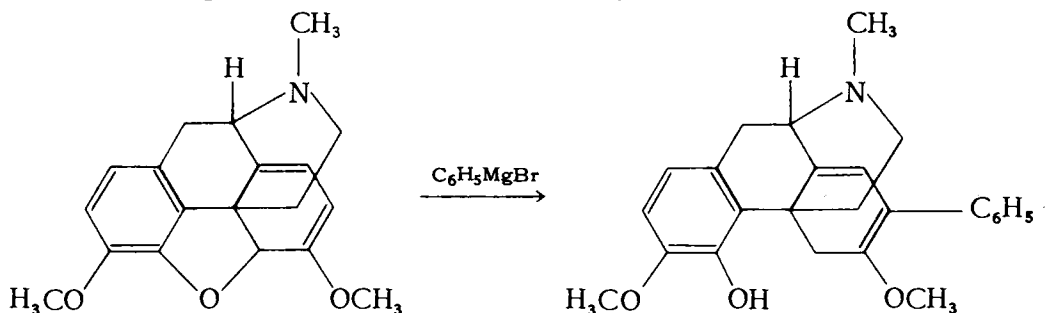


⁴³ Paul, *Bull. soc. chim.*, [4], 53, 417-26 (1933).

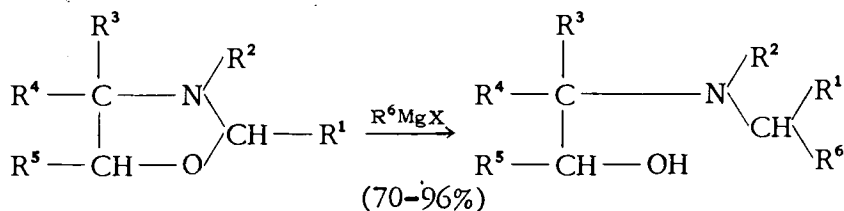
⁴⁴ Kuznetsov, (a) *J. Gen. Chem.* (U.S.S.R.), 9, 2263-8 (1939); *Chem. Abstr.*, 34, 5052 (1940); (b) *J. Gen. Chem.* (U.S.S.R.), 16, 187-92 (1946); *Chem. Abstr.*, 41, 443 (1947).

⁴⁵ Lutz and Reveley, *J. Am. Chem. Soc.*, 63, 3178-80, 3180-9 (1941).

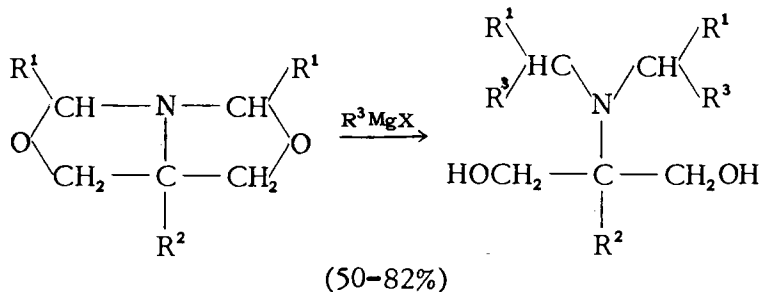
Cherbuliez and Araqui⁴⁶ report that thebaine and desoxycodine react with Grignard reagents with rupture of the oxide rings. Small *et al.*⁴⁷ have also studied the reactions of thebaine (and various more or less related compounds) with Grignard reagents. The reaction of thebaine with phenylmagnesium bromide is tentatively formulated as follows:



Ring-opening reactions which have features in common with the amino ether cleavages reported by Robinson and Robinson (*loc. cit.*³⁵) are described by Senkus.⁴⁸ These involve oxazolidines and 1-aza-3,7-dioxabicyclo[3.3.0]octanes.



($R^6MgX = CH_3MgI, C_2H_5MgBr, i-C_3H_7MgCl$; $i-C_3H_7MgBr$ gives only 35% cleavage product, together with reduction.)



($R^3MgX = C_2H_5MgCl, n-C_3H_7MgCl, n-C_4H_9MgCl, C_6H_5MgBr$)

The relatively mild reaction conditions comprise the addition of an ethereal solution of the cyclic ether to the Grignard solution at the rate of gentle reflux, followed by twenty-four hours standing.

THIO AND SELENO ETHERS

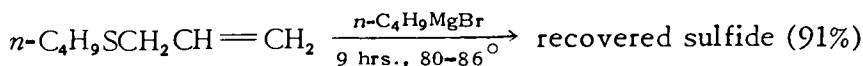
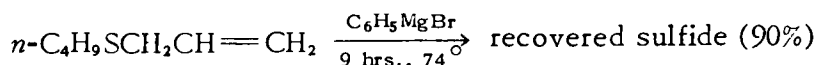
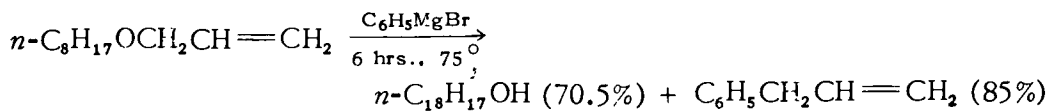
Insofar as one may judge from the very limited data available the thio and seleno ethers are markedly more resistant to Grignard cleavage than are their oxygen analogs.

⁴⁶Cherbuliez and Araqui, *Helv. Chim. Acta*, 26, 2251-2 (1943).

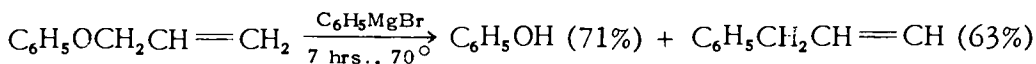
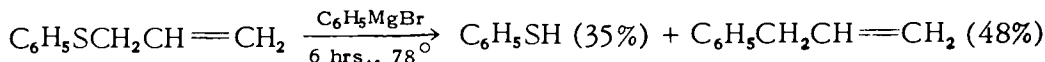
⁴⁷Small, Sargent, and Bralley, *J. Org. Chem.*, 12, 839-68 (1947). (This article contains numerous references to previous work.)

⁴⁸Senkus, *J. Am. Chem. Soc.*, 67, 1515-9 (1945); *Chem. Abstr.*, 41, P2431 (1947).

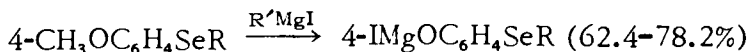
According to Lüttringhaus *et al.*,⁴⁹ allyl *n*-octyl ether undergoes almost complete cleavage upon six hours treatment with phenylmagnesium bromide at 75°, whereas the structurally similar allyl *n*-butyl sulfide is substantially unaffected by nine hours treatment with phenyl- or *n*-butylmagnesium bromide.



The more polar allyl phenyl sulfide is more susceptible to cleavage (Lüttringhaus *et al.*, *loc. cit.*⁴⁹), but apparently less so than the corresponding ether (Lüttringhaus *et al.*⁵⁰).



Keimatsu *et al.*⁵¹ have investigated various methoxyphenyl selenides. The following series of reactions will serve as illustrative.



[R = CH₃ (78.2%); C₂H₅ (62.4%); *n*-C₃H₇ (76.0%); *i*-C₃H₇ (74.5%); *n*-C₄H₉ (76.0%); *i*-C₄H₉ (74.0%); *n*-C₆H₁₃ (74.0%)]

ANOMALOUS ETHER CLEAVAGES

Upon treatment of 3,4,5-trimethoxybenzonitrile with isobutylmagnesium bromide Haller and Schaffer⁵² obtained, in addition to the "normal" reaction product (isobutyl 3,4,5-trimethoxyphenyl ketone), an ordinary ether-cleavage product (isobutyl 3,5-dimethoxy-4-hydroxyphenyl ketone) and a neutral ketone which they tentatively identified as isobutyl 3,5-dimethoxy-4-isobutylphenyl ketone. Hurd and Winberg,⁵³ who repeated and extended this study, found that when reaction is effected by prolonged heating at 40° only the "normal" product is obtained, but that when the reaction is conducted with an excess of Grignard reagent at about 110° two "abnormal" products are obtained in addition to the "normal" product. The identification of the first of the "abnormal" products by Haller and Schaffer (*loc. cit.*⁵²) as isobutyl 3,5-dimethoxy-4-

⁴⁹ Lüttringhaus, Wagner-von Sääf, Sucker, and Borth, *Ann.*, 557, 46-69 (1945).

⁵⁰ Lüttringhaus, von Sääf, and Hauschild, *Ber.*, 71B, 1673-81 (1938).

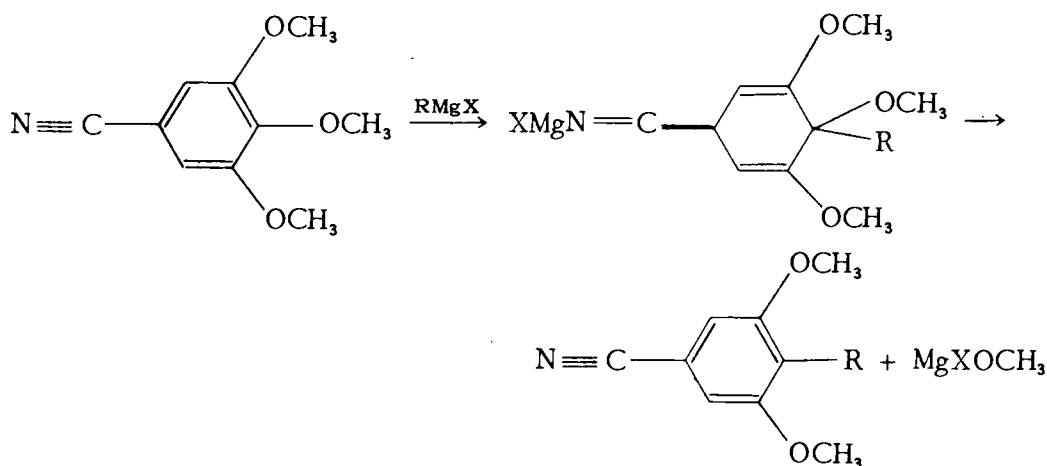
⁵¹ Keimatsu, Yokata, and Sotada, *J. Pharm. Soc. Japan*, 53, 994-1046 (1933); *Chem. Abstr.*, 29, 7300 (1935).

⁵² Haller and Schaffer, *J. Am. Chem. Soc.*, 61, 2175-7 (1939).

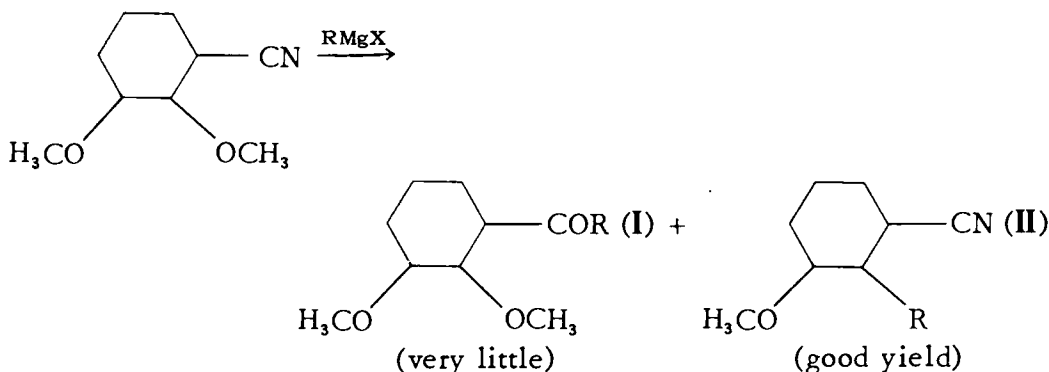
⁵³ Hurd and Winberg, *J. Am. Chem. Soc.*, 64, 2085-6 (1942).

hydroxyphenyl ketone was confirmed by its oxidation to 2,6-dimethoxy-1,4-benzoquinone. The second, although not positively identified, is believed by Hurd and Winberg to have the constitution attributed to it by Haller and Schaffer.

If this identification is correct we have to do here with an anomalous type of ether cleavage which violates the general rule concerning the direction of cleavage of unsymmetrical ethers. It would appear that the most plausible explanation involves 1,6-addition to a conjugated system—possibly $O=C-C=C-C=C$, but more probably $N\equiv C-C=C-C=C$. It has been well-established that among conjugated carbonyl systems, which have been rather extensively investigated (see Chapter VI), 1,6-additions occur, and 1,4-additions involving aromatic rings are well-known. Among conjugated nitrile systems, which have been comparatively little studied (see Chapter X), unequivocal examples of 1,4-addition have nevertheless been observed. It therefore requires but little extension of known facts to postulate some such reaction as:



Similar reactions which presumably involve 1,4-addition have been reported by Richtzenhain⁵⁴ and confirmed by Fuson *et al.*⁵⁵ For example:



[R = C₂H₅ (II, 60%); *i*-C₃H₇ (II, 81%); *n*-C₄H₉ (II, 80%); *i*-C₄H₉ (II, 45%); (CH₂)₅CH (II, 68%); *n*-C₇H₁₅ (II, 62%)]

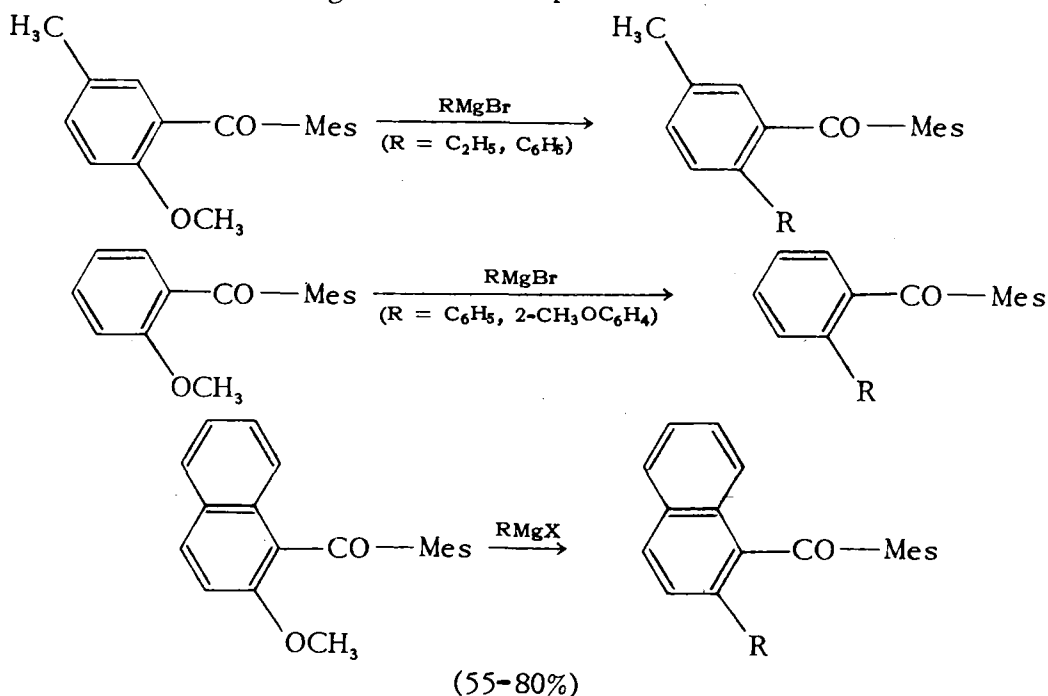
⁵⁴Richtzenhain, *Ber.*, 77B, 1-6 (1944); Richtzenhain and Nippus, *ibid.*, 77B, 566-72 (1944).

⁵⁵Fuson, Gaertner, and Chadwick, *J. Org. Chem.*, 13, 489-95 (1948).

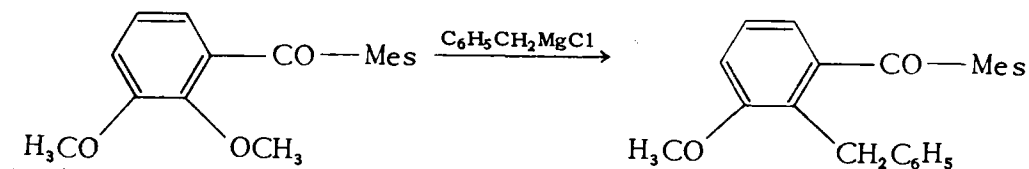
Incidentally, the foregoing exemplary reactions (Richtzenhain and Nippus, *loc. cit.*⁵⁴) are carried out under relatively mild conditions. An ethereal solution of the nitrile is added slowly to an ethereal solution of the Grignard reagent. After subsidence of the fairly vigorous reaction the mixture is allowed to stand for four hours and is then treated in the appropriate manner for recovery of the products.

According to Fuson *et al.* (*loc. cit.*⁵⁵), demethoxylation of an *o*-methoxybenzonitrile takes place readily only when there is a second methoxy group in the *meta* (3) position. It was also found by Fuson and Chadwick⁵⁶ that ethylmagnesium bromide and benzylmagnesium chloride react "normally" with 2-methoxy-1-naphthonitrile, *i.e.*, without replacement of the methoxy group.

Demethoxylations, similarly attributable to 1,4- and 1,6-additions to "hindered" conjugated carbonyl systems have been reported by Fuson and Speck,⁵⁷ Fuson and Gaertner,⁵⁸ Fuson and Tull,⁵⁹ Fuson and Shealy,⁶⁰ and Fuson and Hornberger.⁶¹ For example:



[RMgX = CH₃MgI (56%); C₂H₅MgBr (80%); *n*-C₄H₉MgBr (55%); C₆H₅MgBr (59%); 1-C₁₀H₇MgBr (76%)]



⁵⁶ Fuson and Chadwick, *J. Org. Chem.*, 13, 484-8 (1948).

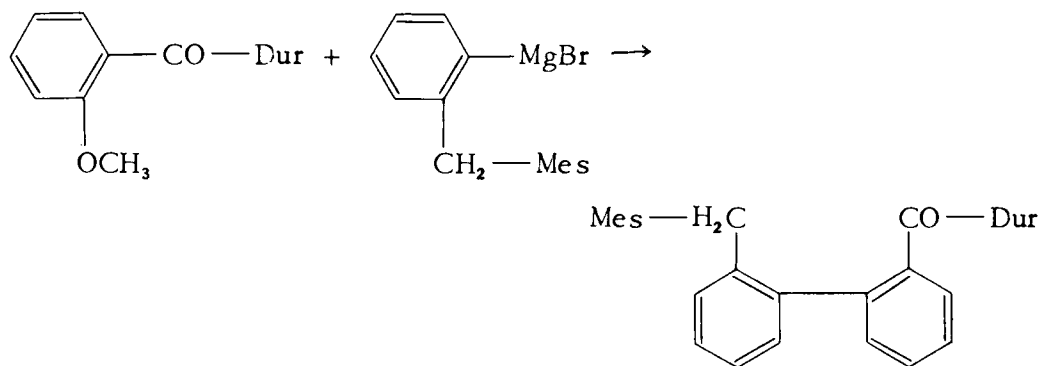
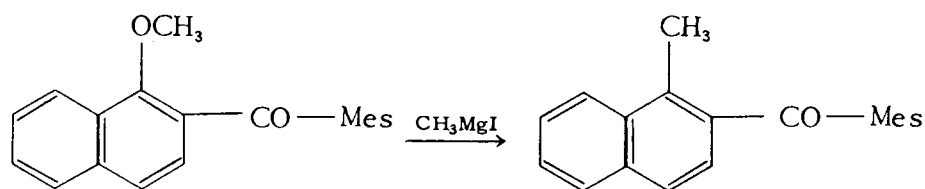
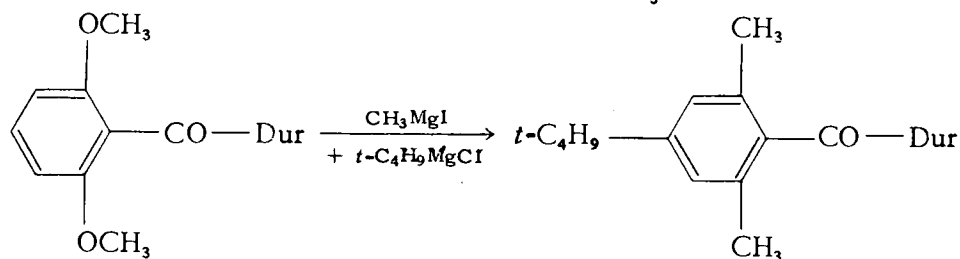
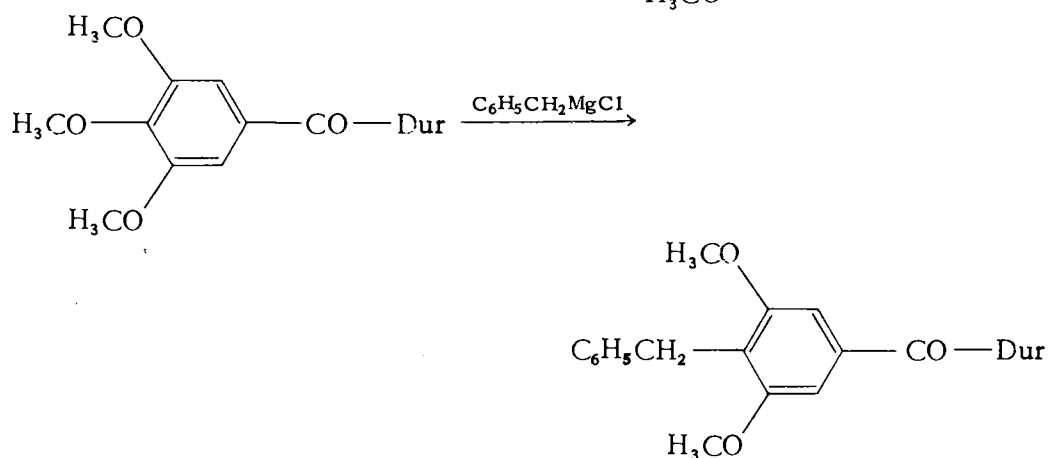
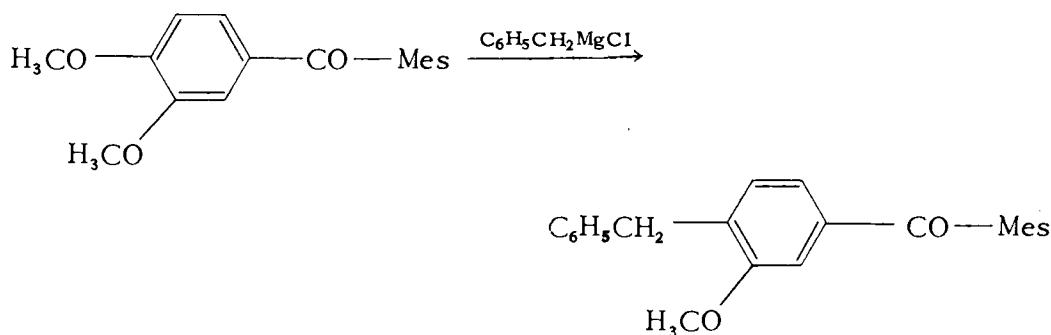
⁵⁷ Fuson and Speck, *J. Am. Chem. Soc.*, 64, 2446-8 (1942).

⁵⁸ Fuson and Gaertner, *J. Org. Chem.*, 13, 496-501 (1948).

⁵⁹ Fuson and Tull, *J. Am. Chem. Soc.*, 71, 2543-6 (1949).

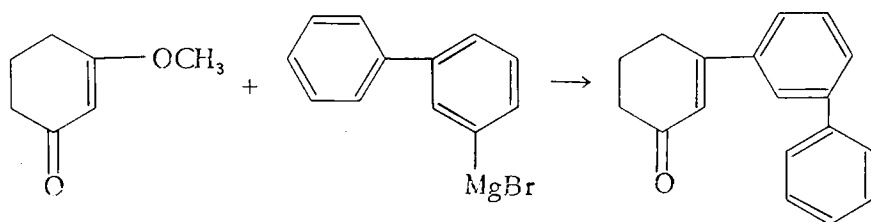
⁶⁰ Fuson and Shealy, *J. Org. Chem.*, 16, 643-7 (1951).

⁶¹ Fuson and Hornberger, *J. Org. Chem.*, 16, 631-6 (1951).

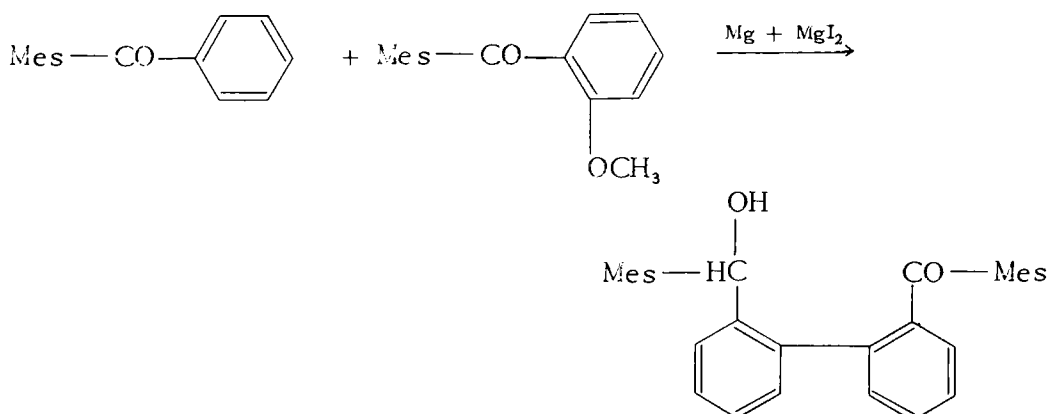


A similar demethoxylation of 3-methoxy-2-cyclohexen-1-one is reported by Woods and Reed.⁶²

⁶² Woods and Reed, *J. Am. Chem. Soc.*, 71, 1348-54 (1949).

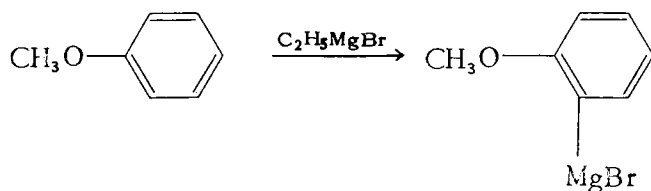


Reductive coupling of hindered ketones with methoxyl cleavage has been reported by Fuson and Hornberger.⁶³

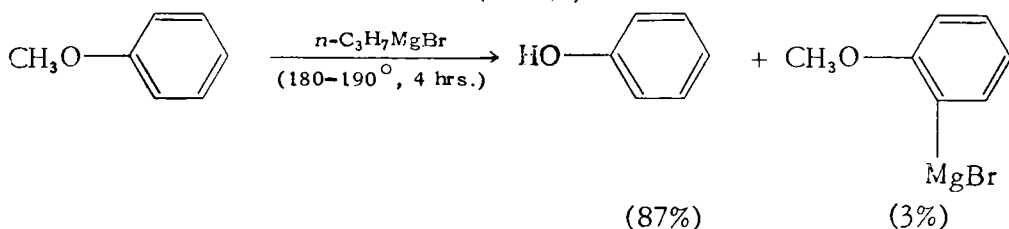


GRIGNARD REAGENTS FROM ETHERS

The preparation of Grignard reagents from aryl alkyl ethers, albeit in rather poor yields, has been reported by Challenger and Miller.⁶⁴

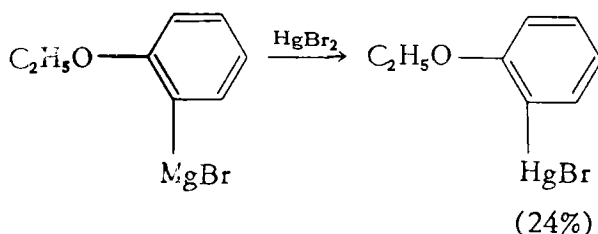
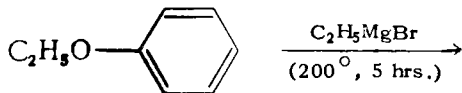


(9-11%)



(87%)

(3%)

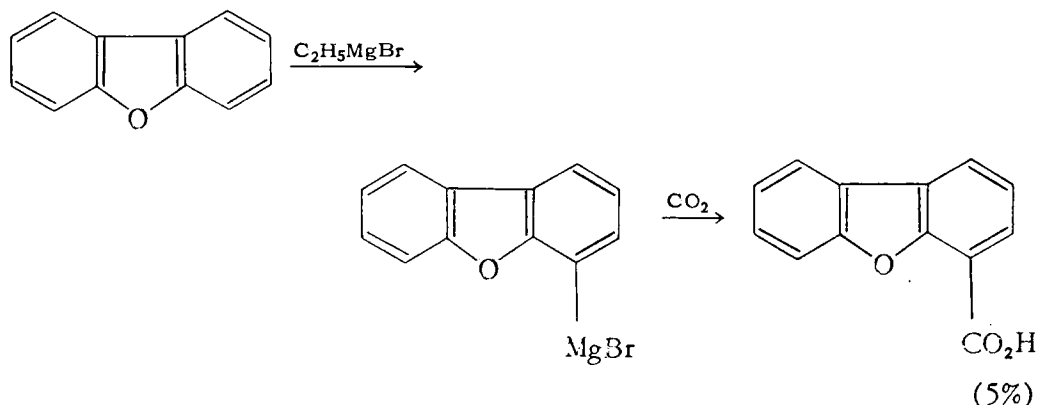


(24%)

⁶³Fuson and Hornberger, *J. Org. Chem.*, 16, 637-42 (1951).

⁶⁴Challenger and Miller, *J. Chem. Soc.*, 1938, 894-9.

A similar reaction of dibenzofuran has been observed by Gilman and Haubein.⁶⁵



ACETALS AND KETALS

Apparently the reactions of acetals and ketals with Grignard reagents, as constituting a possible method for the synthesis of ethers, were first investigated by Späth,⁶⁶ although nearly simultaneous independent studies were made by Tschitschibabin and Jelgasin.⁶⁷

Nothing of any theoretical significance has been reported in this field, but it appears fairly evident that these reactions, like those of the ortho esters, which are discussed elsewhere (see Chapter VIII), represent special cases of ether cleavage. Obviously *gem* alkoxy groups are mutually activating with respect to this reaction.

Representative data are assembled in Table XV-IV. In addition it is reported by Levina *et al.*⁶⁸ that the only isolable product of the reaction of the ethyl ketal of cyclohexanone with methylmagnesium iodide is cyclohexanol, and by Nazarov⁶⁹ that the "cyclic acetal" of $\text{CH}_3\text{COC}(\text{CH}_3)_2\text{OH}$ does not react with methylmagnesium iodide.

⁶⁵ Gilman and Haubein, *J. Am. Chem. Soc.*, 67, 1033-4 (1945).

⁶⁶ Concerning priority claim see: Späth, *Ber.*, 47, 766-8 (1914).

⁶⁷ Tschitschibabin and Jelgasin, *Ber.*, 47, 48-50, 1843-52 (1914).

⁶⁸ Levina, Kulikov, and Parshikov, *J. Gen. Chem. (U.S.S.R.)*, 11, 567-72 (1941); *Chem. Abstr.*, 35, 6931 (1941).

⁶⁹ Nazarov, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1940, 195-202; *Chem. Abstr.*, 36, 742 (1942).

TABLE XV-IV

REACTIONS OF GRIGNARD REAGENTS ($R'''MgX$) WITH ACETALS $[RCH(OR'')]_2$ AND KETALS $[RR'C(OR'')]_2$

Acetal or Ketal	$R'''MgX$	Temp. (Time)	Product(s)	Ref.
$H_2C(OCH_3)_2$	C_6H_5MgI	$120-130^\circ$ (2 hrs.)	$C_6H_5CH_2OCH_3$ (15%)	1
$H_2C(OCH_3)_2$	$C_6H_5CH_2MgCl$	<i>ca.</i> 95° (2 hrs.)	$C_6H_5CH_2CH_2OH + C_6H_5CH_3 +$ $(C_6H_5CH_2-)_2$	2
$H_2C(OCH_3)_2$	$C_6H_5CH_2MgCl$	<i>ca.</i> 100° (8 hrs.)	$C_6H_5CH_3 + (C_6H_5CH_2-)_2$	2
$H_2C(OCH_3)_2$	$C_6H_5CH_2MgCl$	150° (1 hr.)	$C_6H_5CH_3 + C_6H_5CH_2CH_2OCH_3$	2
$H_2C(OC_2H_5)_2$	$n-C_4H_9C \equiv CMgBr$	95° (1 hr.)	$n-C_4H_9C \equiv CCH_2OC_2H_5$ (31-35%)	3
$H_2C(OC_2H_5)_2$	$C_6H_5CH_2MgCl$	150°	$C_6H_5CH_3 + (C_6H_5CH_2)_2CH_2$	2
$H_2C(OC_2H_5)_2$	$4-CH_3OC_6H_4MgI$	<i>ca.</i> 120° (14 hrs.)	$4-CH_3OC_6H_4CH_2OC_2H_5$ (14%)	1
$H_2C(OC_2H_5)_2$	$3,4-(CH_3)_2C_6H_3MgI$	$120-130^\circ$ (4 hrs.)	$3,4-(CH_3)_2C_6H_3CH_2OC_2H_5$ (13%)	1
$H_2C(O-n-C_3H_7)_2$	$(\equiv CMgBr)_2$	95° (1 hr.)	$(\equiv CCH_2OC_2H_5)_2$ (31-35%)	3
$H_2C(O-n-C_3H_7)_2$	$n-C_4H_9C \equiv CMgBr$	95° (1 hr.)	$n-C_4H_9C \equiv CCH_2O-n-C_3H_7$ (31-35%)	3
$H_2C(O-i-C_4H_9)_2$	$C_6H_5CH_2MgCl$	125°	$(C_6H_5CH_2)_2CH_2$ (trace)	2
$BrCH_2CH(OC_2H_5)_2$	C_6H_5MgBr	110° (6 hrs.)	$BrCH_2(C_6H_5CH_2)CHOC_2H_5$ (22%) + $C_6H_5(C_6H_5CH_2)CHOC_2H_5$	4
$BrCH_2CH(OC_2H_5)_2$	$4-CH_3C_6H_4MgBr$	100° (12 hrs.)	$BrCH_2(4-CH_3C_6H_4)CHOC_2H_5 +$ $4-CH_3C_6H_4(4-CH_3C_6H_4CH_2)CHOC_2H_5$ (11%)	4
$ClCH_2CH(OC_2H_5)_2$	$4-ClC_6H_4MgBr$	Room temp.	$ClCH_2(4-ClC_6H_4)CHOC_2H_5$ (65%)	4
$ClCH_2CH(OC_2H_5)_2$	$4-ClC_6H_4MgBr$	$120-130^\circ$ (0.5 hr.)	$(4-ClC_6H_4C \equiv)_2$ (53%, crude)	4
$ClCH_2CH(OC_2H_5)_2$	C_6H_5MgBr	120° (1.5 hr.)	$C_6H_5(C_6H_5CH_2)CHOC_2H_5$ (31%) + $(C_6H_5CH \equiv)_2$	4
$ClCH_2CH(OC_2H_5)_2$	$2-CH_3C_6H_4MgBr$	$120-130^\circ$	$(2-CH_3C_6H_4CH \equiv)_2 +$ $2-CH_3C_6H_4(2-CH_3C_6H_4CH_2)CHOC_2H_5$	4
$ClCH_2CH(OC_2H_5)_2$	$4-CH_3C_6H_4MgBr$	Room temp.	$ClCH_2(4-CH_3C_6H_4)CHOH$ (50%)	4
$ClCH_2CH(OC_2H_5)_2$	$3,4-(CH_3)_2C_6H_3MgBr$	115° (0.5 hr.)	$3,4-(CH_3)_2C_6H_3[3,4-(CH_3)_2C_6H_3CH_2]-$ $CHOC_2H_5$ (17.5%)	4
$CH_3CH(OC_2H_5)_2$	$(\equiv CMgBr)_2$	95° (1 hr.)	$[\equiv CCH(OC_2H_5)CH_3]_2$ (46-49%)	3
$CH_3CH(OC_2H_5)_2$	$HC \equiv CMgBr$	95° (1 hr.)	$CH_3(HC \equiv C)CHOC_2H_5$ (46-49%)	3

TABLE XV-IV (Continued)

Acetal or Ketal	R'''MgX	Temp. (Time)	Product(s)	Ref.
CH ₃ CH(OC ₂ H ₅) ₂	<i>i</i> -C ₄ H ₉ MgBr	<i>ca.</i> 95°	CH ₃ (<i>i</i> -C ₄ H ₉)CHOC ₂ H ₅	2
CH ₃ CH(OC ₂ H ₅) ₂	<i>i</i> -C ₅ H ₁₁ MgBr	100° (16 hrs.)	CH ₃ (<i>i</i> -C ₅ H ₁₁)CHOC ₂ H ₅ (27%)	1
CH ₃ CH(OC ₂ H ₅) ₂	C ₆ H ₅ MgBr	100–150° (1 hr.)	CH ₃ (C ₆ H ₅)CHOC ₂ H ₅ (55%)	1
CH ₃ CH(OC ₂ H ₅) ₂	C ₆ H ₅ MgBr	<i>ca.</i> 95°	CH ₃ (C ₆ H ₅)CHOC ₂ H ₅ (50%)	2
CH ₃ CH(OC ₂ H ₅) ₂	C ₆ H ₅ CH ₂ MgCl	<i>ca.</i> 95°	CH ₃ (C ₆ H ₅ CH ₂)CHOC ₂ H ₅	2
CH ₃ CH(OC ₂ H ₅) ₂	<i>n</i> -C ₅ H ₁₁ C≡CMgBr	95° (1 hr.)	CH ₃ (<i>n</i> -C ₅ H ₁₁ C≡C)CHOC ₂ H ₅ (46–49%)	3
CH ₃ CH(OC ₂ H ₅) ₂	4-Methylcyclohexyl-MgBr	<i>ca.</i> 95°	1-Ethoxy-1-(4-methylcyclohexyl)-ethane	2
HC≡CCH(OC ₂ H ₅) ₂	CH ₃ MgBr	"hot"	CH ₃ (HC≡C)CHOC ₂ H ₅	6,14
HC≡CCH(OC ₂ H ₅) ₂	C ₂ H ₅ MgBr	b. Et ₂ O (several hrs.)	C ₂ H ₅ (HC≡C)CHOC ₂ H ₅	14,13
HC≡CCH(OC ₂ H ₅) ₂	C ₆ H ₅ MgBr	b. Et ₂ O (several hrs.)	C ₆ H ₅ (HC≡C)CHOC ₂ H ₅	14,13
ClCH ₂ CHBrCH(OCH ₃) ₂	<i>n</i> -C ₃ H ₇ MgBr	"cold"	ClCH ₂ CHBr(<i>n</i> -C ₃ H ₇)CHOCH ₃	5
ClCH ₂ CHBrCH(OCH ₃) ₂	<i>n</i> -C ₄ H ₉ MgBr	"cold"	ClCH ₂ CHBr(<i>n</i> -C ₄ H ₉)CHOCH ₃	5
C ₂ H ₅ CH(OC ₂ H ₅) ₂	<i>n</i> -C ₄ H ₉ C≡CMgBr	95° (1 hr.)	C ₂ H ₅ (<i>n</i> -C ₄ H ₉ C≡C)CHOC ₂ H ₅ (46–49%)	3
C ₂ H ₅ OCH ₂ CH(OC ₂ H ₅) ₂	C ₆ H ₅ MgBr	100–200° (1 hr.)	C ₂ H ₅ OCH ₂ (C ₆ H ₅)CHOC ₂ H ₅ (40%)	1
C ₆ H ₅ CH(OC ₂ H ₅) ₂	HC≡CMgBr	95° (1 hr.)	HC≡C(C ₆ H ₅)CHOC ₂ H ₅ (66%)	3
C ₆ H ₅ CH(OC ₂ H ₅) ₂	C ₆ H ₅ MgBr	<i>ca.</i> 95°	(C ₆ H ₅) ₂ CHOC ₂ H ₅ (trace) + (C ₆ H ₅) ₃ CH	7
C ₆ H ₅ CH(OC ₂ H ₅) ₂	<i>n</i> -C ₄ H ₉ C≡CMgBr	95° (1 hr.)	C ₆ H ₅ (<i>n</i> -C ₄ H ₉ C≡C)CHOC ₂ H ₅ (66%)	3
<i>n</i> -C ₄ H ₉ C≡CCH(OC ₂ H ₅) ₂	<i>n</i> -C ₄ H ₉ C≡CMgBr	95° (1 hr.)	(<i>n</i> -C ₄ H ₉ C≡C) ₂ CHOC ₂ H ₅ (66%)	3
<i>n</i> -C ₆ H ₁₃ CH(OC ₂ H ₅) ₂	C ₂ H ₅ MgBr	—	C ₂ H ₅ (<i>n</i> -C ₆ H ₁₃)CHOC ₂ H ₅ + <i>n</i> -C ₆ H ₁₃ (C ₂ H ₅) ₂ CH	8
<i>n</i> -C ₆ H ₁₃ CH(OC ₂ H ₅) ₂	<i>i</i> -C ₅ H ₁₁ MgCl	—	<i>i</i> -C ₅ H ₁₁ (<i>n</i> -C ₆ H ₁₃)CHOC ₂ H ₅ + <i>n</i> -C ₆ H ₁₃ (<i>i</i> -C ₅ H ₁₁) ₂ CH	8
<i>n</i> -C ₆ H ₁₃ CH(OC ₂ H ₅) ₂	C ₆ H ₅ MgBr	—	C ₆ H ₅ (<i>n</i> -C ₆ H ₁₃)CHOC ₂ H ₅ + <i>n</i> -C ₆ H ₁₃ (C ₆ H ₅) ₂ CH	8
<i>n</i> -C ₆ H ₁₃ CH(OC ₂ H ₅) ₂	C ₆ H ₅ CH ₂ MgCl	—	<i>n</i> -C ₆ H ₁₃ (C ₆ H ₅ CH ₂)CHOC ₂ H ₅ + <i>n</i> -C ₆ H ₁₃ (C ₆ H ₅ CH ₂) ₂ CH	8
<i>n</i> -C ₆ H ₁₃ CH(OC ₂ H ₅) ₂	1-C ₁₀ H ₇ MgBr	—	<i>n</i> -C ₆ H ₁₃ (1-C ₁₀ H ₇)CHOC ₂ H ₅	8
(C ₆ H ₅) ₂ CClCH(OC ₂ H ₅) ₂	C ₆ H ₅ MgBr	180°	C ₆ H ₅ Cl (10%) + (C ₆ H ₅) ₂ CH ₂ (36%) + (C ₆ H ₅) ₂ CHCO ₂ H (52%)	9

TABLE XV-IV (Continued)

<u>Acetal or Ketal</u>	<u>R'''MgX</u>	<u>Temp. (Time)</u>	<u>Product(s)</u>	<u>Ref.</u>
$C_9H_{15}CH=CHCHOCH_2CH(OC_2H_5)_2$ *	CH_3MgI	—	$CH_3(C_9H_{15}CH=CHCHOCH_2)CHOC_2H_5$ *	10
$(CH_3)_2C(OC_2H_5)_2$	$i-C_4H_9MgBr$	—	$i-C_4H_9(CH_3)_2COC_2H_5$ (10–15%)	2
$(CH_3)_2C(OC_2H_5)_2$	C_6H_5MgBr	Dist'n Et_2O	$C_6H_5(CH_3)_2COC_2H_5$ (7%)	11
$(CH_3)_2C(OC_2H_5)_2$	$(CH_2)_5CHMgCl$	—	$(CH_2)_5CH(CH_3)_2COC_2H_5$ (7%)	11
$CH_3(C_6H_5)C(OC_2H_5)_2$	$n-C_3H_7MgCl$	80–90 °	$CH_3(n-C_3H_7)(C_6H_5)COC_2H_5$ (59%)	1
$C_6H_5(C_6H_5CH=CH)C(OCH_3)_2$	C_6H_5MgBr	Dist'n Et_2O	$C_6H_5CH=CH(C_6H_5)_2COCH_3$ (57%)	12

* C_9H_{15} = 2,6,6-trimethyl-1-cyclohexenyl.

REFERENCES FOR TABLE XV-IV

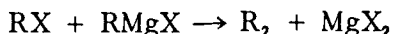
- (1) Späth, *Monatsh.*, 35, 319-32 (1914).
- (2) Tschitschibabin and Jelgasin, *Ber.*, 47, 1843-52 (1914).
- (3) Kranzfelder and Vogt, *J. Am. Chem. Soc.*, 60, 1714-6 (1938).
- (4) Späth, *Monatsh.*, 35, 463-74 (1914).
- (5) Quelet and Pineau, *Compt. rend.*, 222, 1237-8 (1946); *Chem. Abstr.*, 40, 5397 (1946).
- (6) Grard, *Compt. rend.*, 189, 541-3 (1929).
- (7) Tschitschibabin and Jelgasin, *Ber.*, 47, 48-50 (1914).
- (8) Grinberg, *Soobschenie o Nauch.-Issledovatel. Rabote Kiev. Ind. Inst.*, 2, 30-2 (1940); *Khim. Referat. Zhur.*, 4, No. 2, 41 (1941); *Chem. Abstr.*, 37, 2077 (1943).
- (9) Scheibler and Schmidt, *Ber.*, 67B, 1514-8 (1934).
- (10) Shantz, *J. Am. Chem. Soc.*, 68, 2553-7 (1946).
- (11) Levina, Kulikov, and Parshikov, *J. Gen. Chem. (U.S.S.R.)*, 11, 567-72 (1941); *Chem. Abstr.*, 35, 6931 (1941).
- (12) Straus and Ehrenstein, *Ann.*, 442, 93-118 (1925).
- (13) Grard, *Compt. rend.*, 189, 925-7 (1929); *Chem. Abstr.*, 24, 2719 (1930).
- (14) Grard, *Ann. chim.*, [10], 13, 336-81 (1930).

CHAPTER XVI

Reactions of Grignard Reagents with Alkyl, Aralkyl, and Cycloalkyl Halides

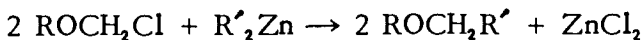
EARLY STUDIES

It was early observed by Grignard and others¹ that the formation of an organomagnesium halide from an organic halide and metallic magnesium is accompanied by side-reactions, among them the formation of Wurtz products. Houben² suggested that the Wurtz products might arise in part at least from the reaction



and investigated this possibility to the extent of studying the reaction of benzyl chloride with methylmagnesium iodide. For reasons that will appear, Houben's reagent-pair was not an optimum selection for the purpose in mind; neither, however, did it represent the worst possible selection. Under the experimental conditions employed by him yields of 25 percent or less of ethylbenzene were realized.

The reaction was used by several investigators³ for the preparation of ethers of higher carbon content from α -halo ethers, evidently in extension of the method of Henty:⁴



Grignard⁵ was able to prepare phenyl phenethyl ether in *ca.* 83 percent yield from β -bromophenetole and phenylmagnesium bromide, but found that with the same bromo ether isoamylmagnesium bromide or benzylmagnesium chloride gave rise principally to ether cleavage. Henry⁶ reported

¹See, e.g.: Tissier and Grignard, *Compt. rend.*, 132, 683-5 (1901); *J. Chem. Soc.*, 80, 1, 316 (1901); *Chem. Zentr.*, 1901, 1, 999; Tschelinzew, *J. Russ. Phys.-Chem. Soc.*, 36, 549-54 (1903); *Chem. Zentr.*, 1904, 11, 183; Tiffeneau, *Compt. rend.*, 139, 481-2 (1904); *Chem. Zentr.*, 1904, 11, 1038.

²Houben, *Ber.*, 36, 3083-6 (1903).

³Hamonet, *Compt. rend.*, 138, 813-4, 975-7, 1609-12 (1904); *J. Chem. Soc.*, 86, 1, 401, 467, 705 (1904); Houben and Führer, *Ber.*, 40, 4990-5000 (1907); Zeltner and Tarassoff, *ibid.*, 43, 941-5 (1910); Lespieau and Bresch, *Compt. rend.*, 156, 712 (1913); *Chem. Abstr.*, 7, 2213 (1913).

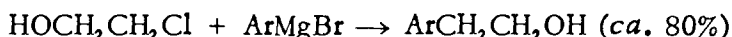
⁴Henry, *Compt. rend.*, 113, 368-70 (1892); *J. Chem. Soc.*, 62, 27 (1892).

⁵Grignard, *Compt. rend.*, 138, 1048-50 (1904); *J. Chem. Soc.*, 86, 1, 494 (1904).

⁶Henry, *Rec. trav. chim.*, 26, 106-15 (1906).

the preparation of hexamethylethane in *ca.* 33 percent yield from pentamethylethyl bromide and methylmagnesium bromide. Gomberg and Cone⁷ obtained poor yields (5-10 percent) of tetraphenylmethane from the reaction of triphenylmethyl chloride with phenylmagnesium bromide but nearly quantitative yields of unsymmetrical tetraphenylethane from the reaction of the same chloride with benzylmagnesium chloride.

Grignard⁸ also reported the preparation of various alcohols by the reactions of organomagnesium halides with halohydrins, *e.g.*:*



However, there is reasonable doubt that α, β -halohydrin reactions are, in general, simple halide-Grignard reagent reactions—a point which will be discussed further.

Späth⁹ was the first to undertake a truly systematic study of the reactions of Grignard reagents with alkyl halides (see Table XVI-I, reference 212). Unlike Abegg,¹⁰ who had proposed an ionic theory of Grignard reagent reactions, Späth concluded that these reactions are essentially free-radical processes, of which the first stage may be represented as follows:



He accounted for the final products observed as resulting from the various possible reactions of the free radicals:

- (1) $\text{R}\cdot + \text{R}'\cdot \rightarrow \text{RR}'$
- (2) $\text{R}\cdot + \text{R}\cdot \rightarrow \text{R}_2$
- (3) $\text{R}\cdot + \text{R}'\cdot \rightarrow \text{R}_{(-\text{H})} + \text{R}'\text{H}$
- (4) $\text{R}\cdot + \text{R}\cdot \rightarrow \text{R}_{(-\text{H})} + \text{RH}$
- (5) $\text{R}_{(-\text{H})} + \text{R}'\cdot + \text{R}''\cdot \rightarrow \text{R}'\text{R}_{(-\text{H})}\text{R}''$

Equation 5 was invoked to account for the supposed production of 1,2,3-triphenylpropane (actually 1-phenyl-2-*p*-benzylphenylethane¹¹) in the reaction of benzyl chloride with methylmagnesium iodide. To these Späth might well have added:

- (3a) $\text{R}\cdot + \text{R}'\cdot \rightarrow \text{R}_{(+\text{H})} + \text{R}'_{(-\text{H})}$
- (3b) $\text{R}'\cdot + \text{R}'\cdot \rightarrow \text{R}'_{(-\text{H})} + \text{R}'_{(+\text{H})}$
- (4a) $\text{R}'\cdot + \text{R}'\cdot \rightarrow \text{R}'_2$

⁷Gomberg and Cone, *Ber.*, 39, 1461-70 (1906).

⁸Grignard, *Compt. rend.*, 141, 44-6 (1905); *J. Chem. Soc.*, 88, I, 593 (1905); *Ann. chim.*, [8], 10, 23-40 (1905).

*Ar = C₆H₅, 2-CH₃C₆H₄, 4-CH₃OC₆H₄, 1-C₁₀H₇.

⁹Späth, *Monatsh.*, 34, 1965-2014 (1913).

¹⁰Abegg, *Ber.*, 38, 4112-6 (1905).

¹¹See: Fuson, *J. Am. Chem. Soc.*, 48, 2937-42 (1926).

Of the supposed free-radical reactions the first was the only one at that time regarded as having preparative value. Empirically, Späth generalized that alkyl halides (except the methyl) give poor yields according to equation 1. Somewhat better yields are obtained in such reactions with phenylmagnesium bromide than with alkylmagnesium halides. Favorable results (with respect to equation 1) may be expected when the carbon atom attached to the halogen atom is made more "positive" by suitable substitution (as in the α -halo ethers, the chlorohydrins, and the arylated methyl halides). The use of iodides, either as Grignard reagent co-reactants or as starting materials for the preparation of Grignard reagents, in general, is to be avoided. To these may be added the observation, since made by many others (see Table XVI-I), that allyl and structurally related bromides and chlorides usually react with Grignard reagents to give excellent yields of alkenes.

SPECULATIONS CONCERNING REACTION MECHANISMS

Reconsideration of Späth's data in the light of a materially enhanced knowledge of reaction mechanisms in general and of the reactions of free radicals in solution in particular, combined with consideration of the wealth of additional data since contributed by others, leads to the conclusion that no single reaction mechanism accounts adequately for the initial step of all types of reactions observed. In attempting to assign reasonably probable reaction mechanisms to various types of reaction it is necessary to take into consideration the natures of the reactants, the reaction conditions imposed, and the products obtained.

The "normal" reaction. As a point of departure one may well choose for consideration the type of reaction which, on the basis of common usage, has the best claim to designation as the "normal" reaction. Such a reaction is usually conducted in ethereal solution under relatively mild conditions (between room temperature and the boiling point of ethyl ether) and results in a good yield (~ 70 percent) of "condensation" product (RR'). Among the reactions listed in Table XVI-I which fulfill these conditions are most of the reactions of allyl halides and many of the reactions of α -halo ethers and mono-, di-, and triarylmethyl halides. In general, the halides ($R'X$) which give good yields of "condensation" products (RR') under mild experimental conditions have two characteristics in common: (1) a relatively polar carbon-halogen bond (which is to say that the radical R' is rather weakly "electronegative"¹²); and (2) relatively high resistance to loss of a *beta* hydrogen atom.

It seems highly improbable, even on *a priori* grounds, that these are free-radical reactions. For one thing, a free-radical process would seem

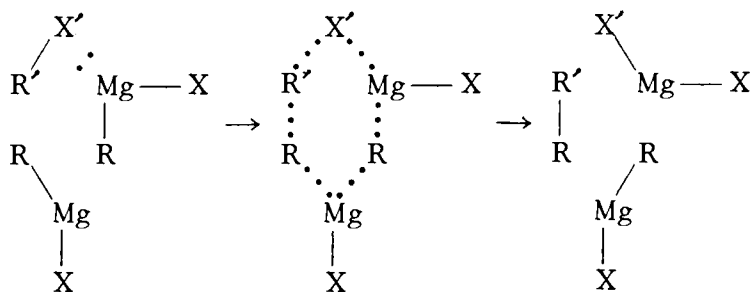
¹²For a discussion of the relative "electronegativities" of organic radicals see: Kharasch and Reinmuth, *J. Chem. Education*, 5, 404-18 (1928); 8, 1703-48 (1931); Kharasch, Reinmuth, and Mayo, *ibid.*, 11, 82-96 (1934); 13, 7-19 (1936).

to require a more nearly statistical distribution of products among RR' , R_2 , and R'_2 (or the corresponding disproportionation products, $R_{(-H)}$, $R_{(+H)}$, $R'_{(-H)}$, $R'_{(+H)}$). For another, present knowledge of the behavior of free radicals in solution would lead to the prediction that such relatively reactive radicals as the methyl or phenyl would attack such a relatively good hydrogen donor as ethyl ether long before they had opportunity to encounter, and react with, other free radicals.

Moreover it is now well-known that when reaction conditions that give rise to the production of free radicals from Grignard reagents are deliberately induced (as by the addition to the system of cobaltous halides) the ensuing reaction takes a course quite other than the "normal" one (see section on "Coupling" Reactions; see also Chapter V).

On the whole it appears more profitable to treat the "normal" condensation of a Grignard reagent with an organic halide as a special case of solvolysis in which the Grignard reagent plays the rôle usually assigned to a polar solvent. In view of the present somewhat controversial status of the general solvolysis theory,* it might appear that the principal incentive to such a decision is a disposition to embrace familiar uncertainties in preference to flying to others unknown. Nevertheless this course would appear to place the problem in its proper classification and to offer the best prospects for an ultimate satisfactory solution. Quite possibly it will eventually be found that no single mechanism is adequate to account for all examples of "normal" condensation.

On *a priori* grounds, a working hypothesis embodying a concerted "push-pull" mechanism of the kind proposed by Swain has obviously attractive features. Incidentally, such a mechanism could be (though it need not necessarily be) formulated in terms of a quasi six-membered ring transition state.

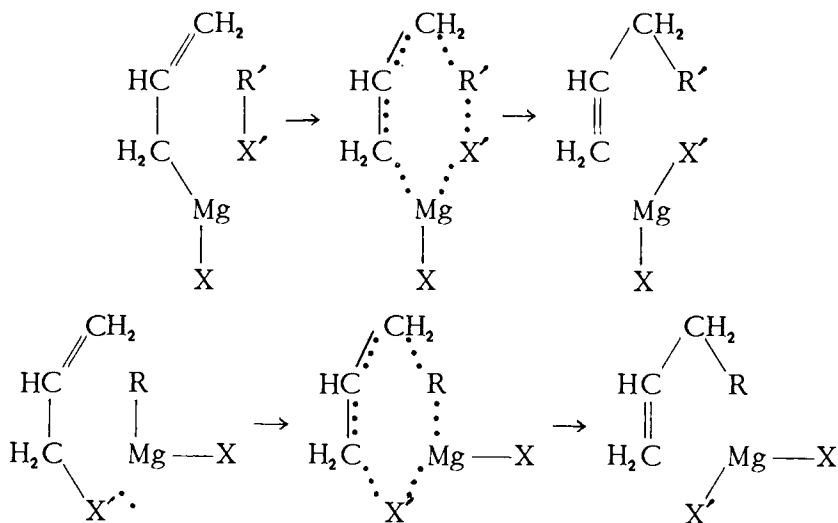


Superficially, at least, it would appear, however, that, for an irreversible solvolysis, such a process would require retention of optical activity (with inversion of configuration) when an optically active halide is one of the reactants.

*Any attempt to incorporate into this discussion an adequate critical review of present solvolysis theories would be inordinately space-consumptive. The reader unfamiliar with this field may find a fair summary of divergent views, with numerous leading references, in articles by Swain, *J. Am. Chem. Soc.*, 70, 1119-28 (1948), and Winstein, Grunwald, and Jones, *ibid.*, 73, 2700-7 (1951).

Unfortunately, this point has not been extensively investigated. There is, nevertheless, the testimony of Letsinger and Traynham¹³ to the effect that benzylmagnesium chloride reacts with (–)-2-bromobutane ($[\alpha]_D^{25} - 16.80$) to give a 17 percent yield of 1-phenyl-2-methylbutane ($[\alpha]_D^{25} + 0.64$), on which basis it is estimated that approximately 91 percent of the asymmetry of the alkyl group is lost in the condensation reaction. This observation in itself, however, is not sufficient to eliminate from consideration a concerted "push-pull" mechanism, or even an S_N2 mechanism, unless it can be demonstrated that, under the reaction conditions imposed, (1) halogen exchange between the alkyl halide and the MgX_2 component of the Grignard reagent is negligible or very slow as compared to the "normal" condensation reaction, or/and (2) that the first portion of the corresponding R_2Mg reaction (during which the concentration of the MgX_2 component of the Grignard reagent is negligibly small) results in substantially the same degree of racemization. It may or may not be significant in this connection that in the analogous reaction of benzylsodium with (+)-2-bromobutane the degree of racemization is much smaller (≤ 26 percent.)¹⁴

In the special cases of the reactions of allylic Grignard reagents with alkyl halides, or of ordinary Grignard reagents with allylic halides, there is the possibility that a special second-order reaction mechanism may supersede in whole or in part the mechanism (or mechanisms) prevailing in ordinary condensations.

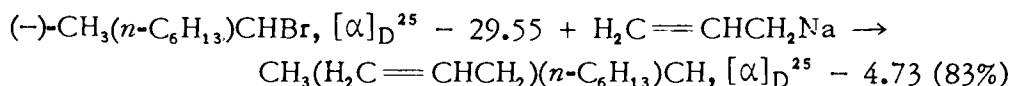
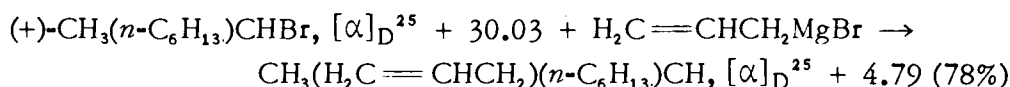


The first of these suggested reaction schemes would also seem to imply a retention of optical activity (with inversion) when the alkyl halide is optically active, although there would still be the possibility of halide racemization through halogen exchange already suggested. It may or may not be significant in this connection that both allylmagnesium bromide and allylsodium react with 2-bromoöctane to give good yields of 4-methyl-

¹³Letsinger and Traynham, *J. Am. Chem. Soc.*, 72, 849-52 (1950).

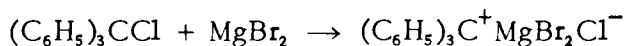
¹⁴Letsinger, *J. Am. Chem. Soc.*, 70, 406-9 (1948).

1-decene in the formation of which relatively little (13-21 percent) racemization has taken place (Letsinger and Traynham, *loc. cit.*¹³).

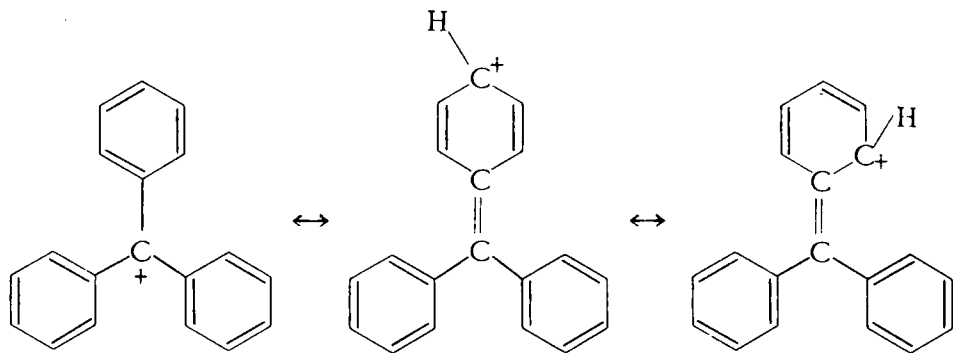


Concerning the allylic Grignard reagents, there arises the question whether or not there is any such thing as structure, in the sense ordinarily understood by the organic chemist, in a system involving a resonant anion. This point is discussed in more detail in connection with the allylic rearrangements (*q.v.*, Chapter XVII).

As regards the triarylmethyl halides (and probably some of the less arylated methyl halides) it seems probable that the "normal" Grignard reaction is predominantly of the $\text{S}_{\text{N}}1$ type. The addition of an ethyl ethereal solution of magnesium bromide (or zinc chloride) to an ethereal or ether-benzene solution of triphenylmethyl chloride causes an immediate color-development which has been attributed to the formation of a quinonoid addition compound.¹⁵ It seems likely that the "addition compound" is an ion-pair resulting from ionization in the sense:



The carbonium ion is a resonance-stabilized structure to which the following forms (and others like them) make contributions:



The poor yields (5-10 percent) of tetraphenylmethane obtained when triphenylmethyl chloride or bromide is treated with ethereal phenylmagnesium bromide^{16,17,18,19,20} have sometimes been attributed to steric hindrance, and no doubt steric effects do play a part in inhibition of the "normal" condensation, but due consideration should also be given to the relatively high activation energy necessary to establish a covalent linkage between a resonance-stabilized carbonium ion corresponding to a

¹⁵Schoepfle and Trepp, *J. Am. Chem. Soc.*, 58, 791-4 (1936).

¹⁶Gilman and Jones, *J. Am. Chem. Soc.*, 51, 2840-3 (1929).

¹⁷Gomberg and Cone, *Ber.*, 39, 1461-70 (1906).

¹⁸Gomberg and Kamm, *J. Am. Chem. Soc.*, 39, 2009-15 (1917).

¹⁹Meyer, *J. prakt. Chem.*, [2], 82, 521-38 (1910).

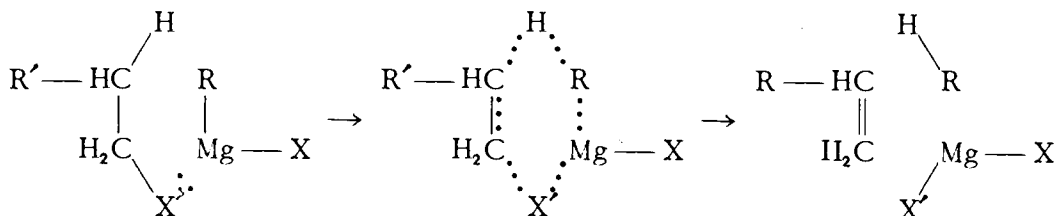
²⁰Freund, *Ber.*, 39, 2237-8 (1906).

very weakly "electronegative" radical and a carbanion corresponding to a strongly "electronegative" radical. The methyl and benzyl Grignard reagents, admittedly somewhat less subject to steric influence than the phenyl, but also with carbanions corresponding to radicals considerably less "electronegative" than the phenyl, give excellent yields of the respective "normal" condensation products with triarylmethyl chlorides.^{17,10,21}

Somewhat better yields (21-29 percent) of tetraphenylmethane are obtained when the phenylmagnesium bromide-triphenylmethyl chloride reaction is conducted in benzene solution (or suspension).²² The principal competing reaction under these conditions is a *para* condensation leading to the formation of diphenyl-*p*-biphenylmethane. Doubtless the analogous *ortho* condensation would encounter prohibitive steric hindrance. When *para* condensation is "blocked," as in 4,4',4''-tribromo- and 4,4',4''-trichlorotriphenylmethyl chloride the yields of tetraarylmethanes obtained with phenylmagnesium bromide may approach 50 percent.²²

Dehydrohalogenation and dehalogenation. When the radical R' of a halide R'X' contains a highly reactive *beta* hydrogen atom, or when a *beta* hydrogen atom is available and the condensation reaction, for steric or other reasons, is very slow, dehydrohalogenation of the halide may compete with, or completely outrun, the condensation reaction. Thus, when treated with methylmagnesium bromide in boiling ethyl ethereal solution, isobornyl chloride is 90 percent dehydrochlorinated in an hour, no appreciable condensation having taken place in the meanwhile. The evolved gas is pure methane.²³ *Cis*- and *trans*-1-chloro-2-methylcyclohexane behave alike when refluxed for twenty-eight hours with ethereal methylmagnesium bromide. Each yields *ca.* 10 percent of condensation product and *ca.* 33 percent of dehydrochlorination product, together with pure methane (Kharasch *et al.*, *loc. cit.*²³).

Whereas these reactions so much resemble Grignard reagent reduction reactions (*q.v.*, Chapter VI) in reverse, the impulse to propose for them a bimolecular mechanism involving a quasi six-membered ring transition state is well-nigh irresistible.



It would be interesting to learn whether or not the relative proportions of competing dehydrohalogenation and condensation reactions could be

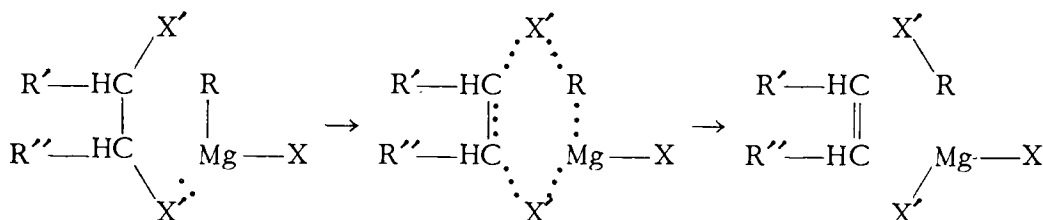
²¹Späth, *Monatsh.*, 34, 1695-2014 (1913).

²²Schoepfle and Trepp, *J. Am. Chem. Soc.*, 58, 791-4 (1936).

²³Kharasch, Engelmann, and Urry, *J. Am. Chem. Soc.*, 66, 365-7 (1944).

altered by loading the system with magnesium halide, as is the case with competing carbonyl reduction and addition reactions (*q.v.*, Chapter VI). Such an experiment would probably have the best chance of returning an affirmative answer if slow inverse addition were employed and if the reaction medium were incapable of forming magnesium complexes. For example, a benzene suspension of phenylmagnesium and magnesium bromides might be combined, by slow dropwise addition, with a refluxing suspension of magnesium bromide in benzene-ethyl bromide solution.* The scales, thus weighted in favor of a trimolecular (as opposed to a bimolecular) process, might register an improvement in the yield of the condensation product.

Whatever the mechanism of the dehydrohalogenation reactions, it is probable that the related process of dehalogenation (in the case of adjacent dihalides) is similar. As a tentative working hypothesis the following scheme is suggested.



CONDENSATIONS WITH ACETYLENIC GRIGNARD REAGENTS

The acetylenic Grignard reagents, which are atypical in many respects, exhibit peculiarities in their behavior toward allyl bromide. Nieuwland *et al.*²⁴ have reported that, in general, the 1-alkynylmagnesium bromides, when prepared with magnesium of high purity, are totally inert toward allyl bromide, one of the more reactive alkyl halides with respect to Grignard condensation. For example, no reaction between 1-hexynylmagnesium bromide and allyl bromide took place in an ethyl ethereal solution intermittently stirred at room temperature for twenty-three days. Similar inertia characterized benzene or amyl ethereal solutions refluxed for two to twelve hours. When, however, 2 g. of cuprous chloride per mole of Grignard reagent was added to an ethyl ethereal solution, condensation proceeded rapidly, resulting in an 88 percent yield of "normal" product. Cuprous bromide and cuprous cyanide also proved effective catalysts, as did the cupric halides (which are immediately reduced to cuprous compounds by most Grignard reagents).

Grignard and Lepayre,²⁵ on the other hand, have reported the "normal" condensation, with 70 percent yield, of phenylethynylmagnesium bromide

*A Soxhlet extractor operated under a nitrogen atmosphere would provide a convenient means of Grignard reagent addition. This device has been employed by Schoepfle and Trepp, *J. Am. Chem. Soc.*, 58, 791-4 (1936).

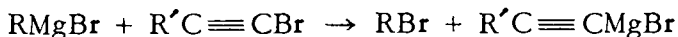
²⁴Danehy, Killian, and Nieuwland, *J. Am. Chem. Soc.*, 58, 611-2 (1926).

²⁵Grignard and Lepayre, *Bull. soc. chim.*, [4], 43, 141-2 (1928); *Compt. rend.*, 192, 250-3 (1931); *Chem. Abstr.*, 25, 2421 (1931).

with allyl bromide. The inference is, however, that their magnesium contained traces of copper.

Whereas cuprous halides are well-known to form complexes with both olefinic and acetylenic compounds (see section on 1,4-Addition, Chapter VI), these condensations by themselves would raise the question whether cuprous catalysis is effected through activation of the unsaturated halide, of the acetylenic Grignard reagent, or both. Ostensibly uncatalyzed "normal" condensations of various acetylenic Grignard reagents with α -halo ethers and other halides have been reported (see Table XVI-I), but chiefly by European investigators, who, for the most part, have operated with magnesium of a lower degree of purity than that available to American investigators of recent years. If these condensations prove, on further investigation, to have been copper-catalyzed then copper catalysis must be attributed primarily to activation of the acetylenic Grignard reagent.

Another peculiarity of the acetylenic Grignard reagents is to be found in their condensations with the corresponding acetylenic iodides, reported by Grignard and Tcheoufaki.²⁶ The interaction of an alkylmagnesium bromide and an acetylenic bromide consists in a functional exchange^{27,28} (see Acetylenic Hydrocarbons, p. 70).



The analogous interaction of a 1-alkynylmagnesium bromide and the corresponding 1-alkynyl bromide would result in no observable net change unless "tagged" bromine were employed. According to Grignard and Tcheoufaki, however, the reactions of phenylethynyl- and 1-heptynylmagnesium iodides with the corresponding acetylenic iodides yield condensation products.



On the basis of the presently available evidence it is uncertain whether or not such condensations are peculiar to the acetylenic iodides. Neither is it evident whether or not such condensations are copper-catalyzed.

"COUPLING" REACTIONS

Paradoxically enough the "coupling" reactions of Grignard reagents with organic (chiefly aralkyl) halides have been the subjects of more intensive study, and are in some respects better understood theoretically, than the so-called "normal" condensation reactions. Some of our ideas concerning the "normal" reactions are drawn by inference from the ways in which they differ from the "coupling" reactions.

²⁶Grignard and Tcheoufaki, *Bull. soc. chim.*, [4], 43, 42-3 (1928).

²⁷Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 36, 1545-51 (1904); *Bull. soc. chim.*, [3], 36, 177 (1906).

²⁸Kharasch, Lambert, and Urry, *J. Org. Chem.*, 10, 298-306 (1945).

For reasons which will appear in the ensuing discussion the "coupling" reactions are adjudged to be free-radical processes; they are characterized by dimerization of the radical of the organic halide. Usually the principal product resulting from the attempt to condense phenylmagnesium bromide with triphenylmethyl chloride in ethyl ethereal solution is that of the "coupling" reaction (hexaphenylethane).^{29,30}

All coupling reactions have in common the characteristic that the relatively weakly "electronegative" radical of the organic halide is unreactive toward the solvent (and other reaction-system components) and that it either shows relatively little tendency to disproportionate or is structurally incapable of disproportionation. Such reactions may, however, be divided into two general classes.

Of the first class, the reaction of triphenylmethyl chloride with phenylmagnesium bromide to form hexaphenylethane (already discussed) is representative. According to the hypothesis proposed this is, in a sense, a "hindered" reaction. Because of the difficulty of "normal" combination of a positive ion derived from a very weakly "electronegative" radical (of the organic halide) and a negative ion derived from a strongly "electronegative" radical (of the Grignard reagent) the reaction takes an alternative course. The reaction of α -naphthylmagnesium bromide with di- α -naphthylmethyl chloride³¹ constitutes another example.

In the second class of "coupling" reactions there may be said to be a predisposition toward the free-radical mechanism in that the Grignard reagent or the alkyl halide, or both, have some tendency toward homolytic dissociation. In reactions of this class the radical of the organic halide need not be so weakly "electronegative," nor need the radical of the Grignard reagent be strongly "electronegative." Organomagnesium iodides are most effective, and in some cases will effect "coupling" when the corresponding bromides or chlorides show little or no tendency to do so. Methylmagnesium iodide is ordinarily the preferred reagent.

The reaction of methylmagnesium iodide with benzyl chloride will serve as illustrative. This reaction was first investigated by Houben,³² who did not, however, report the "coupling" product, and later by Späth,³³ who isolated some 24 percent of bibenzyl in addition to a 35 percent yield of the "normal" product (ethylbenzene).^{*} More recently it has been studied in some detail by Fuson.³⁴ Under the experimental conditions

²⁹Meyer, *J. prakt. Chem.*, [2], 82, 521-38 (1910).

³⁰Gomberg and Kamm, *J. Am. Chem. Soc.*, 39, 2009-15 (1917).

³¹Schmidlin and Massini, *Ber.*, 42, 2377-92 (1909).

³²Houben, *Ber.*, 36, 3083-6 (1903).

³³Späth, *Monatsh.*, 34, 1695-2014 (1913).

^{*}Späth³³ believed that he had also isolated small amounts of 1,2,3-triphenylpropane, and proposed a mechanism to account for its formation. However, it has been shown by Fuson³⁴ that this byproduct is actually 4-benzylbibenzyl, formed by the condensation of excess benzyl chloride with the "coupling" product (bibenzyl).

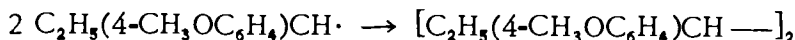
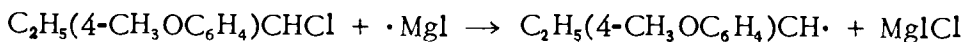
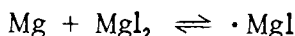
³⁴Fuson, *J. Am. Chem. Soc.*, 48, 2681-9, 2937-42 (1926).

employed by him the reaction resulted in a 23-27 percent yield of "normal" product (ethylbenzene), a 31-33 percent yield of "coupling" product (bibenzyl), and a gas which he characterized as ethane (33-35 percent). The identification of the gas was made upon the basis of the volume contraction upon combustion in a Hempel burette, and the further volume contraction upon carbon dioxide absorption. From what is now known of the behavior of free methyl radicals in ethereal solution, however, it would appear that the gas identification must be partially in error. Under such conditions methyl radicals do not dimerize, although some ethane may be formed by attack of the radicals on the methyl Grignard reagent. For the most part, however, the methyl radicals react with ethyl ether; the gaseous products are methane, ethane, and ethylene. Similar reactions of various benzyl halide derivatives have been reported by Fuson *et al.*³⁵ Other examples are to be found in Table XVI-I.

A rather interesting special case of "coupling" is that of the sterically "hindered" mesitoyl chloride with methylmagnesium iodide.³⁶ When the chloride is added to the Grignard reagent an excellent yield (88 percent) of acetomesitylene is obtained, but when the reversed addition is employed (as is usually recommended for the preparation of ketones from acid halides) the yield of acetomesitylene is greatly reduced (35 percent) and a considerable quantity (39 percent) of bimesitoyl is obtained.

INDUCED "COUPLING" REACTIONS

The hypothesis that "coupling" is a free-radical reaction suggests that suitable experimental devices might be invoked to induce "coupling" reactions that ordinarily would not occur spontaneously. The possible potentialities of magnesious iodide in this connection naturally come to mind. As the basis for a critical experiment designed to furnish an unequivocal answer to a theoretical question this device is somewhat lacking in appeal, for the necessary experimental conditions rather closely approximate those of the Wurtz reaction, which would result in the same product. As a practical expedient, however, this device has not been entirely overlooked, for a Japanese patent³⁷ describes the "coupling" of anethole hydrochloride with magnesium iodide and metallic magnesium. Presumably the significant reactions are:



³⁵Fuson, *J. Am. Chem. Soc.*, 48, 830-6, 2681-9 (1926); Fuson and Ross, *ibid.*, 55, 720-3 (1933); Fuson, Denton, and Kneisley, *ibid.*, 63, 2652-3 (1941); Fuson, Horning, Ward, Rowland, and Marsh, *ibid.*, 64, 30-3 (1942); Fuson, Kneisley, Rabjohn, and Ward, *ibid.*, 68, 533 (1946).

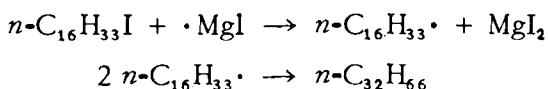
³⁶Fuson and Corse, *J. Am. Chem. Soc.*, 60, 2063-6 (1938).

³⁷Aoyama Scientific Research Inst., Inc., *Japanese Patent*, 162,577, March, 7, 1944; *Chem. Abstr.*, 42, P4200 (1948). Concerning a similar magnesium (possibly Mg-MgBr₂) coupling see: Docken and Spielman, *J. Am. Chem. Soc.*, 62, 2163-4 (1940).

In the available abstract the yield is not stated. In view of the source, the lack of experimental detail, and the non-critical nature of the experiment, no theoretical significance should be attributed to this report. It is of interest chiefly because of the working hypothesis implied.

Oldham and Ubbelohde,³⁸ describe "a modified Grignard reaction in the synthesis of hydrocarbons." The method consists in the preparation of a Grignard reagent from a long-chain normal alkyl halide and magnesium in the usual manner. The Grignard reagent is then treated by successive alternate additions of iodine and metallic magnesium, with cooling during iodine additions and reflux prior and subsequent to magnesium additions. In a specific example the Grignard reagent was prepared from 20.3 g. of hexadecyl iodide and 2.1 g. of magnesium in 80 ml. of ether. Five additions of iodine (7.5, 5.8, 4.3, 3.2, and 2.4 g.) were made, alternating with five additions of magnesium (1.4, 1.1, 0.8, 0.6, and 0.4 g.). A yield of 70 percent of dotriacontane was obtained. As might be expected, this was accompanied by some disproportionation products.

It would appear that the significant portion of this process may be entirely analogous to that already outlined.

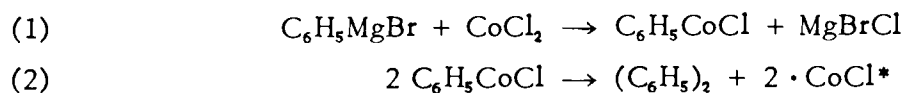


If so, the preliminary formation of a Grignard reagent and its subsequent decomposition with iodine serves the useful purpose of building up a working concentration of magnesium iodide in the system. Equally satisfactory results might be attainable by a simpler procedure.

It seems likely that other supposed "iodine coupling" reactions effected in the presence of residual magnesium (*e.g.*, that of 1-bromo-1-piperonylethane, described by Lieberman *et al.*³⁹) owe their success at least in part to the action of magnesioid iodide.

However, although the observations cited are consistent with the hypothesis that magnesioid iodide (and probably magnesioid bromide) may serve to induce "coupling" reactions, they cannot be said to prove anything. All are susceptible of alternative interpretation.

A more convincing demonstration of induced coupling is that of anethole hydrobromide by phenylmagnesium bromide in the presence of 5 mole percent of cobaltous chloride to yield up to 42 percent of hexestrol dimethyl ether.⁴⁰ The rôle of cobaltous chloride in the free-radical chain reaction leading to "coupling" may be described as follows:

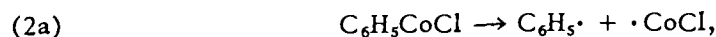


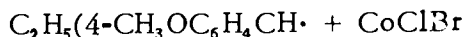
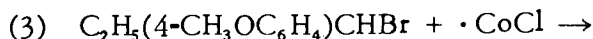
³⁸Oldham and Ubbelohde, *J. Chem. Soc.*, 1938, 201-6.

³⁹Lieberman, Mueller, and Stiller, *J. Am. Chem. Soc.*, 69, 1540-1 (1947).

⁴⁰Kharasch and Kleiman, *J. Am. Chem. Soc.*, 65, 491-3 (1943).

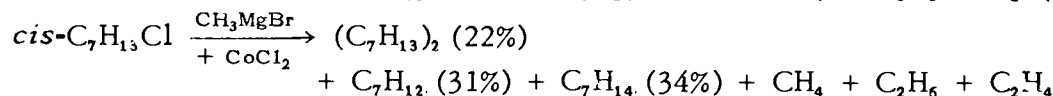
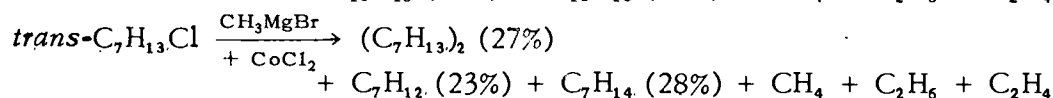
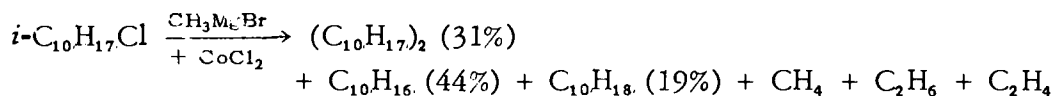
*It is probable that some cobaltous subchloride free radicals are also generated by the process



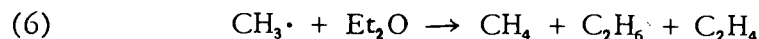
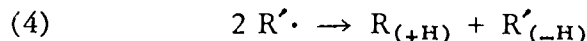
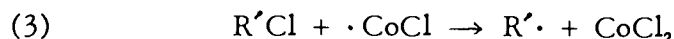
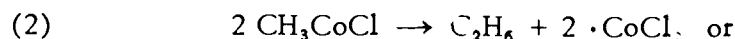


A similar induced "coupling" reaction has been carried out with methylmagnesium bromide, cobaltous chloride, and cinnamyl chloride.⁴¹ Without cobaltous chloride these reactants yield 89 percent of "normal" condensation product and 6 percent of "coupling" products; in the presence of 5 mole percent of cobaltous chloride, 12 percent of "normal" product and a total of 70 percent of "coupling" products are formed. Nickel chloride (NiCl_2) and chromic chloride (CrCl_3) are similarly, though somewhat less, effective.

The reactions of methylmagnesium bromide with isobornyl chloride and with *cis*- or *trans*-1-chloro-2-methylcyclohexane lead principally to dehydrochlorination of the chlorides, with formation of methane. When, however, cobaltous chloride is added to the respective reaction systems, the reactions take a different course, leading to the formation of "coupling" and disproportionation products, together with a gaseous mixture consisting of methane, ethane, and ethylene.⁴²



The effects of cobaltous chloride addition on these reactions are interpreted on the basis of a free-radical chain reaction:



Altogether it appears fairly evident that, in the absence of metallic addenda or impurities, reactions conducted under mild experimental con-

especially in reactions conducted at higher temperatures, but the relatively high yields of biphenyl resulting from reactions of this kind indicate that process 2 must be the predominant reaction [see e.g.; Kharasch and Fields, *J. Am. Chem. Soc.*, 63, 2316-20 (1941); Kharasch, Lewis, and Reynolds, *ibid.*, 65, 493-5 (1943)].

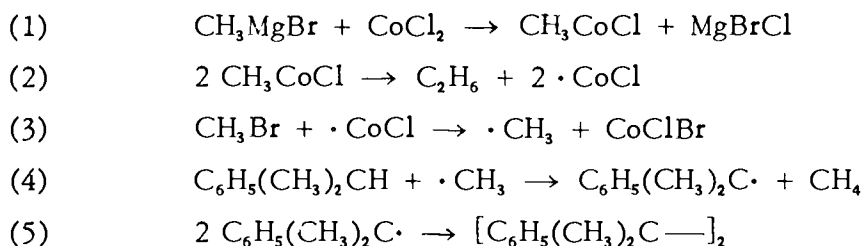
⁴¹Kharasch, Lambert, and Urry, *J. Org. Chem.*, 10, 298-306 (1945).

⁴²Kharasch, Engelmann, and Urry, *J. Am. Chem. Soc.*, 66, 365-7 (1944).

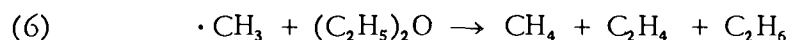
ditions and leading to formation of the "normal" addition product, RR' , or of one-way disproportionation products in the sense $R'_{(-H)} + R_{(+H)}$, or both, are *not* free-radical reactions.

On the other hand "forced" reactions of relatively unreactive halides probably are, and "coupling" reactions certainly are.

It is interesting to note that by use of a suitably chosen intermediary organic halide a process of this kind may be extended one step farther to effect the "coupling" of hydrocarbon residues. Of several examples studied, the interaction of methylmagnesium bromide, cobaltous chloride, methyl bromide, and cumene (isopropylbenzene) in the presence of ethyl ether will serve as illustrative.⁴³



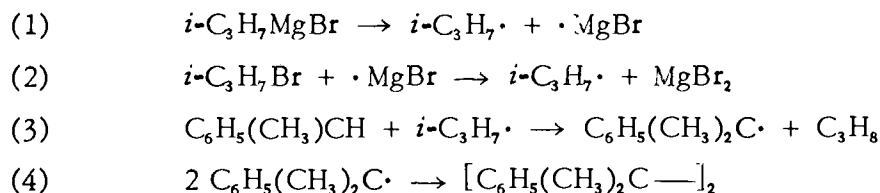
Some of the methyl radicals formed are removed by reaction with the ethyl ether present.



Attempts to conduct the reaction in the total absence of ethyl ether were unsuccessful, probably because of the insolubility of the metallic reactants.

"FORCED" REACTIONS

The study just cited (Kharasch and Urry⁴³) incidentally throws some light on the probable mechanism of "forced" Grignard reactions. Although there was no appreciable reaction between methylmagnesium bromide, an alkyl bromide, and cumene at 100° in the absence of cobaltous chloride, under the same conditions, ethylmagnesium bromide, *n*-propylmagnesium bromide, and isopropylmagnesium bromide all reacted. These reactions are explicable as consequences of (induced) thermal dissociation of the Grignard reagent.



Because the less reactive isopropyl free radicals are more selective in their action than the more reactive methyl radicals, there is relatively little loss of free radicals through attack upon the ether present. There is, however, some loss through disproportionation.

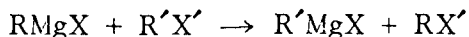
⁴³Kharasch and Urry, *J. Org. Chem.*, 13, 101-9 (1948).

Upon *a priori* grounds it might be predicted that, of corresponding organometallic halides, the iodides should be the most, and the chlorides the least, susceptible to thermal dissociation in the manner just described. With the halogen remaining the same the Grignard reagents with the less electronegative organic radicals should be the more susceptible, and those with the more electronegative radicals the less susceptible, to thermal dissociation. It may be concluded that "forced" reactions in general are predominantly free-radical reactions.

For some reactant pairs there is a considerable amount of free-radical dissociation even under the experimental conditions often employed for the supposedly "normal" reactions. A conspicuous example is the reaction of ethylmagnesium bromide with cyclohexyl bromide at the boiling point of the ethereal reaction system (*ca.* 40°). During reaction under these conditions there is steady evolution of gas (54 percent ethane; 46 percent ethylene). A mixture of cyclohexane and cyclohexene (*ca.* 35 percent unsaturated) may be isolated from the reaction mixture.^{44,*}

FUNCTIONAL EXCHANGE

The suggestion that a functional exchange between Grignard reagent and organic halide, in the sense



might take place was made by Urien⁴⁵ in explanation of the *modus operandi* of Grignard's "entrainment" method for the preparation of organomagnesium halides⁴⁶ (*q.v.*, Chapter II). This idea had previously occurred to Gilman and Jones,⁴⁷ who had investigated the following Grignard reagent-organic halide pairs with negative results: benzylmagnesium chloride, bromobenzene; phenylmagnesium bromide, benzyl chloride; triphenylmethylmagnesium chloride, bromobenzene; benzylmagnesium chloride, triphenylmethyl chloride; phenylmagnesium bromide, triphenylmethyl chloride. Ether-benzene or ether-toluene solutions of the respective reagent pairs were refluxed for about three hours, and were then cooled, carbonated, and hydrolyzed. In no case investigated could any carboxylic acid other than that corresponding to the Grignard reagent originally present be detected.

In a similar study conducted at lower temperature (−5 to 0°), Kharasch and Fuchs (*loc. cit.*⁴⁴) could detect no functional exchange between: *n*-butylmagnesium bromide and bromobenzene; *n*-butylmagnesium bromide and *p*-anisyl bromide; methylmagnesium bromide and *p*-biphenyl bromide; methylmagnesium bromide and 9-chlorofluorene; phenylmagnesium bromide

⁴⁴Kharasch and Fuchs, *J. Org. Chem.*, 10, 292-7 (1945).

*In this study⁴⁴ ordinary reagent-grade magnesium was used in preparation of the Grignard reagent. Conceivably, the use of sublimed magnesium might have led to different results.

⁴⁵Urien, *Compt. rend.*, 198, 1244-6 (1934).

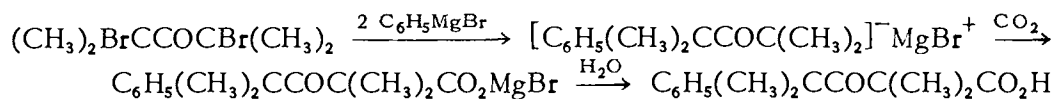
⁴⁶Grignard, *Compt. rend.*, 198, 625-8 (1934).

⁴⁷Gilman and Jones, *J. Am. Chem. Soc.*, 51, 2840-3 (1929).

and *n*-butyl bromide; and *n*-butylmagnesium bromide and 1-bromo-1,2,2-triphenylethene.

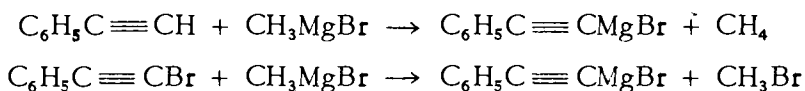
Kharasch and Fuchs (*loc. cit.*⁴⁴) have confirmed in part Urien's (*loc. cit.*⁴⁵) report that cyclohexyl bromide exchanges with ethylmagnesium bromide, but have found that the amount of exchange when the reactants are combined in ethereal solution and the ether is removed by distillation is by no means so great as Urien had supposed. The 40 percent yield of cyclohexane supposedly isolated by Urien upon hydrolysis of the residue so obtained is actually a mixture of cyclohexane and cyclohexene, of which only the relatively small excess of the former over the latter may be attributed to functional exchange. Urien either overlooked or ignored the simultaneous evolution of ethane and ethylene.

The apparent examples of exchange between α -halo ketones and Grignard reagents may be dismissed as special cases of enolate formation in which the enolate is of the kind that behaves like a true Grignard reagent, as does the enolate of acetomesitylene (see α -Halo Ketones, Chapter VI). Such, for instance, are Umnova's⁴⁸ successive reactions of phenylmagnesium bromide and carbon dioxide with α, α' -dibromoisobutyronone:

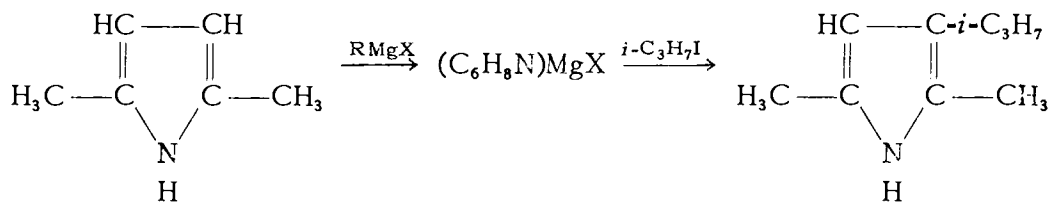


Wuyts⁴⁹ report of the reaction of α -bromocamphor with phenylmagnesium bromide omits experimental detail, but probably should be similarly classified.

The reaction of methylmagnesium bromide with phenylethynylbromide to yield a Grignard reagent⁵⁰ is analogous to the corresponding reaction with phenylacetylene.



The reaction of methylmagnesium iodide with 2,5-dimethyl-3,4-diiodofuran to form a Grignard reagent⁵¹ is also reminiscent of the preparation of a Grignard reagent from 2,5-dimethylpyrrole.⁵²



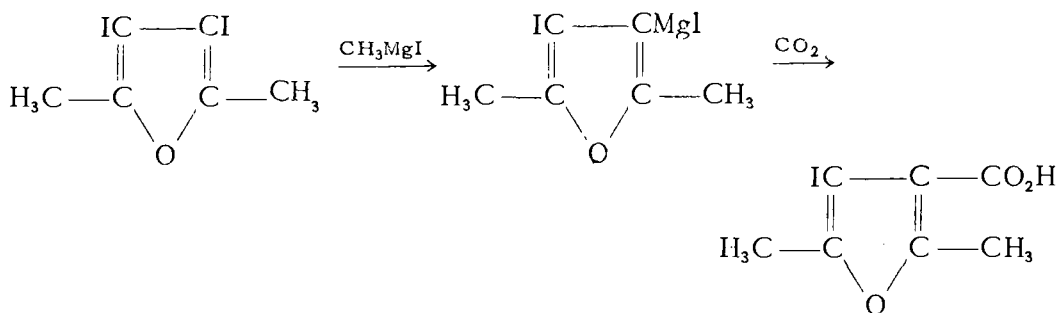
⁴⁸Umnova, *J. Russ. Phys.-Chem. Soc.*, 45, 881-4 (1913); *Chem. Zentr.*, 1913, II, 1478.

⁴⁹Wuyts, *Compt. rend.*, 199, 1317-9 (1934).

⁵⁰Kharasch, Lambert, and Urry, *J. Org. Chem.*, 10, 298-306 (1945).

⁵¹Hurd and Wilkinson, *J. Am. Chem. Soc.*, 70, 739-41 (1948).

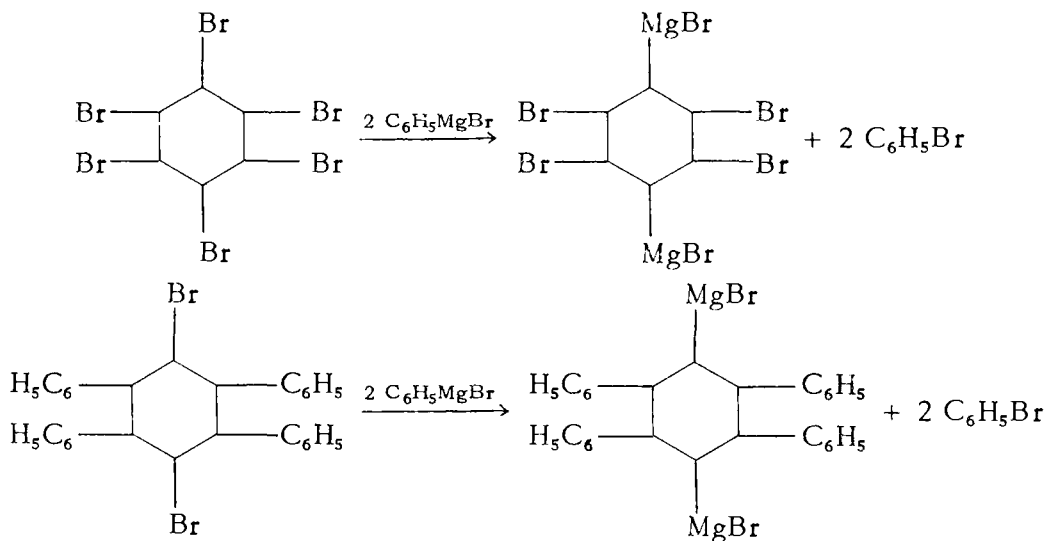
⁵²Plancher and Tanzi, *Atti acad. Lincei*, [5], 23, II, 412-7 (1914); *Chem. Zentr.*, 1915, I, 743; *Chem. Abstr.*, 9, 1477 (1915).



It is quite possible, of course, that this is a free-radical reaction, especially in view of the halide and the Grignard reagent involved. It would be of some interest to know, however, whether or not 2,5-dimethylfuran behaves toward Grignard reagents as though it had an "active" hydrogen atom.

On the basis of the rather limited evidence available one is tempted to generalize tentatively that when an "active hydrogen" compound reacts with a Grignard reagent to form a hydrocarbon and a new Grignard reagent (or pseudo-Grignard reagent) the corresponding halide may reasonably be expected to react with the Grignard reagent to form a new halide and a new Grignard reagent (or pseudo-Grignard reagent).

The fact that 1,2,4,5-tetrabromobenzene and 1,2,4,5-tetraphenylbenzene are the isolable products of the reaction of phenylmagnesium bromide with hexabromobenzene⁵³ suggests that one or more types of exchange, *e.g.*,



may take place in this reaction.*

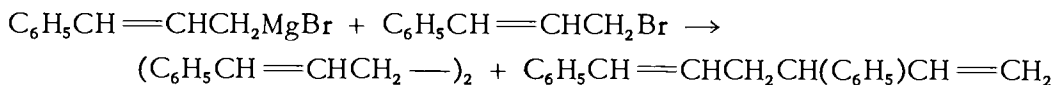
The reported products of reaction of Grignard reagents with hexachloroethane (C_2Cl_4 , $\text{C}_2\text{H}_2\text{Cl}_4$, C_2HCl_5 , 1,1,1,2- $\text{Cl}_4\text{C}_2\text{H}_2$, 1,1,2,2- $\text{Cl}_4\text{C}_2\text{H}_2$)⁵⁴ also strongly suggest exchange, although experimental details are lacking.

⁵³Geissman and Mallatt, *J. Am. Chem. Soc.*, 61, 1788-90 (1939). See also: Dilthey and Hurtig, *Ber.*, 67B, 495-6, 2004-7 (1934).

*Carbonation or other suitable treatment of the reaction mixture might supply more cogent evidence on this point than simple hydrolysis.

⁵⁴Korschak, *J. Gen. Chem. (U.S.S.R.)*, 9, 1153-4 (1939); *Chem. Abstr.*, 34, 1303 (1940); *Chem. Zentr.*, 1940, I, 196.

Prévost⁵⁵ has invoked the concept of exchange to account for the small amounts of "coupling" products obtained in the reaction of ethylmagnesium bromide with cinnamyl bromide, which he attributes to the reaction:



In view of the foregoing discussion of "coupling" reactions this assumption scarcely seems necessary, but the isolation of small amounts of allylbenzene and propenylbenzene indicates that some exchange does in fact take place, and the "coupling" products may well arise in part from the reaction proposed by Prévost.

On the basis of the evidence available it would appear that functional exchange between an organic halide and an organomagnesium halide is a relatively rare reaction, and that when the organic halide involved is not one corresponding to an "active hydrogen" compound, the exchange takes place through a free-radical mechanism.

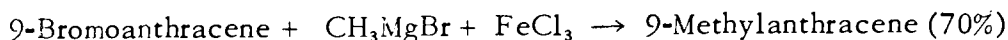
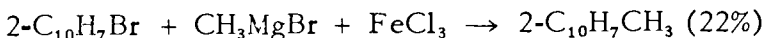
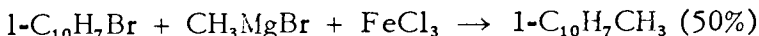
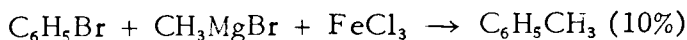
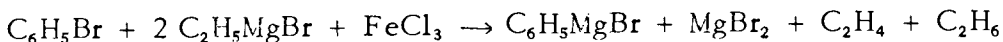
This idea is supported by observations on induced exchange reactions. All the reagent pairs investigated by Kharasch and Fuchs (*loc. cit.*⁴⁴) with negative results showed appreciable exchange in the presence of small amounts of cobaltous chloride. For example 1-bromo-1,2,2-triphenylethene, when treated with *n*-butylmagnesium bromide in the presence of 4 mole percent of cobaltous chloride, carbonated, and subjected to hydrolysis, yielded 14 percent of triphenylacrylic acid. The explanation suggested is:

- (1) $n\text{-C}_4\text{H}_9\text{MgBr} + \text{CoCl}_2 \rightarrow n\text{-C}_4\text{H}_9\text{CoCl} + \text{MgBrCl}$
- (2) $2 n\text{-C}_4\text{H}_9\text{CoCl} \rightarrow \text{C}_4\text{H}_{10} + \text{C}_4\text{H}_8 + 2 \cdot\text{CoCl}$
- (3) $(\text{C}_6\text{H}_5)_2\text{C}=(\text{C}_6\text{H}_5)\text{CBr} + \cdot\text{CoCl} \rightarrow (\text{C}_6\text{H}_5)_2\text{C}=(\text{C}_6\text{H}_5)\text{C}\cdot + \text{CoClBr}$
- (4) $(\text{C}_6\text{H}_5)_2\text{C}=(\text{C}_6\text{H}_5)\text{C}\cdot + n\text{-C}_4\text{H}_9\text{MgBr} \rightarrow$
 $(\text{C}_6\text{H}_5)_2\text{C}=(\text{C}_6\text{H}_5)\text{CMgBr} + \cdot\text{C}_4\text{H}_9$
- (5) $(\text{C}_6\text{H}_5)_2\text{C}=(\text{C}_6\text{H}_5)\text{CBr} + \cdot\text{C}_4\text{H}_9 \rightarrow (\text{C}_6\text{H}_5)_2\text{C}=(\text{C}_6\text{H}_5)\text{C}\cdot + n\text{-C}_4\text{H}_9\text{Br}$

That the exchange reactions of halides corresponding to "active hydrogen" compounds differ from the free-radical exchange reactions is indicated by the behavior of phenylethynyl bromide with methylmagnesium bromide. In the absence of cobaltous chloride exchange occurs spontaneously, and, upon subsequent hydrolysis, an 89 percent yield of phenylacetylene is obtained. Carbonation prior to hydrolysis leads to a 55 percent yield of phenylpropionic acid. When the reaction is carried out in the presence of 5 mole percent of cobaltous chloride a 62 percent yield of 1-propynylbenzene is obtained, together with some tar (Kharasch, Lambert, and Urry, *loc. cit.*⁵⁰). The mechanism of the free-radical reaction in this case invites further investigation.

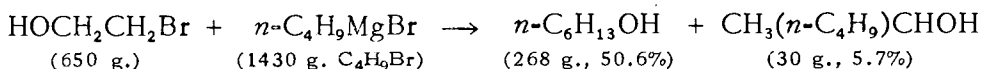
⁵⁵Prevost, *Bull. soc. chim.*, [4], 49, 1372-81 (1931).

Functional exchanges induced by traces of ferric chloride have been reported by Vavon and Mottez⁵⁶ in what appears to have been intended as a preliminary announcement, for no experimental details are given.

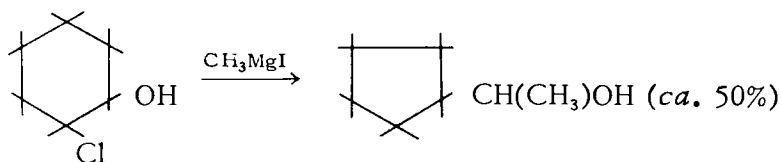


THE HALOHYDRINS*

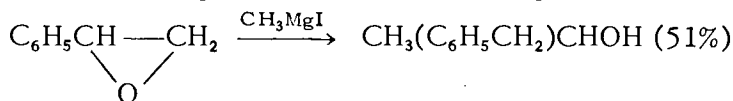
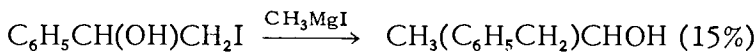
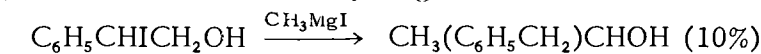
There is nothing in the reported reactions of ethylene chlorohydrin with Grignard reagents to suggest that they are other than the "normal" reactions of an alkyl halide (see Table XVI-I, $\text{C}_2\text{H}_5\text{ClO}$). However, halohydrin reactions that are obviously more complicated are not far to seek. For example, Cottle and Hollyday⁵⁷ have found that the reaction of ethylene bromohydrin with *n*-butylmagnesium bromide yields, in addition to *n*-hexanol (the "normal" product), a relatively small amount of 2-hexanol.



The reaction of 2-chlorocyclohexanol (configuration not specified) with methylmagnesium iodide is reported by Godchot *et al.*⁵⁸ to yield 1-cyclopentylethanol.†



Further, Golumbic and Cottle⁵⁹ report that the two isomeric styrene iodo-hydrins and styrene oxide all yield the same secondary alcohol (1-phenyl-2-propanol) when treated with methylmagnesium iodide.



⁵⁶Vavon and Mottez, *Bull. soc. chim.*, [5], 11, 196 (1944).

*The general chemistry of halohydrins, including Grignard reaction rearrangements, has been reviewed by Tiffeneau, *Bull. soc. chim.*, [5], 12, 453-76 (1945).

⁵⁷Cottle and Hollyday, *J. Org. Chem.*, 12, 510-6 (1947).

⁵⁸Godchot, Bedos, and Cauquil, *Bull. soc. chim.*, [4], 43, 521-2 (1928).

†The use of methylmagnesium bromide or chloride, prepared from sublimed magnesium, in this and similar experiments would eliminate any possible suspicion that the reaction might be of the radical, rather than the ionic, type.

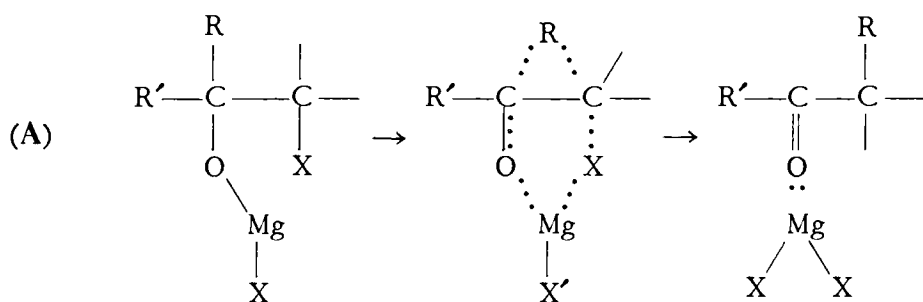
⁵⁹Golumbic and Cottle, *J. Am. Chem. Soc.*, 61, 996-1000 (1939).

Tiffeneau⁶⁰ had early suggested that the apparently "abnormal" products arising from the reactions of Grignard reagents with some α -halo ketones might be attributed to the conversion of the halohydrinates initially formed by "normal" addition of Grignard reagents at carbonyl double bonds to epoxides and the further reaction of the epoxides with excess Grignard reagent. As regards the behavior of some halohydrins (e.g., the iodohydrins of Golumbic and Cottle), this is a fairly plausible hypothesis. As regards some other halohydrin reactions, however, it constitutes an assumption which appears to be neither necessary nor altogether sufficient.

It does not seem adequate, for example, to the elucidation of stereospecific effects in halohydrinate and related rearrangements subsequently observed by Tiffeneau and his collaborators.⁶¹ To cite but one instance, the iodomagnesium derivative of *cis*-1-methyl-2-chlorocyclohexanol, upon heating, is converted to 2-methylcyclohexanone; the corresponding *trans* isomer is converted to acetylcyclopentane. The similarity of these transformations to the familiar pinacol-pinacolone rearrangements is fairly obvious and has been recognized by Tiffeneau.

The most satisfactory general analysis of the subject has been made by Geissman and Akawie,⁶² who have also investigated the thermal transformations of the halomagnesium derivatives of the *cis-trans* stereoisomers of some 2-halo-1-indanols. The *cis* isomers are converted principally, and in rather good yields (ca. 70 percent), to the 1-indanones; the *trans* isomers also yield a little (ca. 7 percent) of the 1-indanones, but are converted chiefly to tarry or resinous materials.

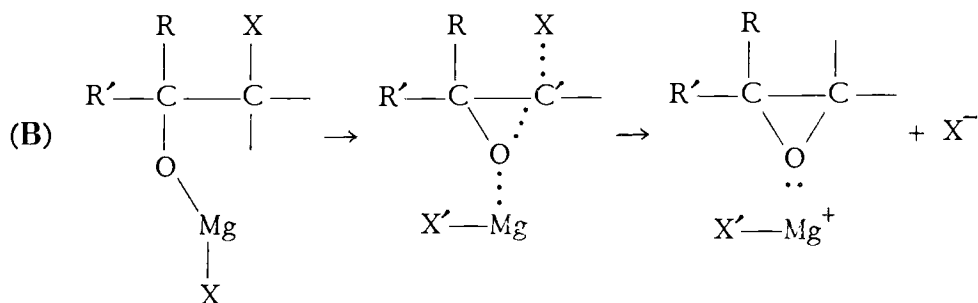
Geissman and Akawie propose that two types (A and B) of halohydrinate transformation are possible. With minor modifications in notation, these may be represented as follows.



⁶⁰Tiffeneau, *Bull. soc. chim.*, [3], 29, 1156-8 (1903).

⁶¹See, e.g.: (a) Tiffeneau and Tchoubar, *Compt. rend.*, 198, 941-3 (1934); *Chem. Abstr.*, 28, 3385 (1934); (b) Tiffeneau and Tchoubar, *Compt. rend.*, 199, 360-2 (1934); *Chem. Abstr.*, 28, 6704 (1934); (c) Tiffeneau and Tchoubar, *Compt. rend.*, 199, 1624-6 (1934); *Chem. Abstr.*, 29, 2515 (1935); (d) Tiffeneau and Tchoubar, *Compt. rend.*, 202, 1931-4 (1936); *Chem. Abstr.*, 8179 (1936); (e) Tiffeneau and Vaissiere, *Compt. rend.*, 209, 449-53 (1939); *Chem. Abstr.*, 34, 386 (1940); (f) Tchoubar, *Compt. rend.*, 212, 195-7 (1941); *Chem. Abstr.*, 36, 6143 (1942); (g) Tiffeneau, Tchoubar, and LeTellier, *Compt. rend.*, 216, 856-60 (1943); *Chem. Abstr.*, 38, 4584 (1944). This work has been reviewed by: (h) Tiffeneau, *Bull. soc. chim.*, [5], 12, 621-7 (1945).

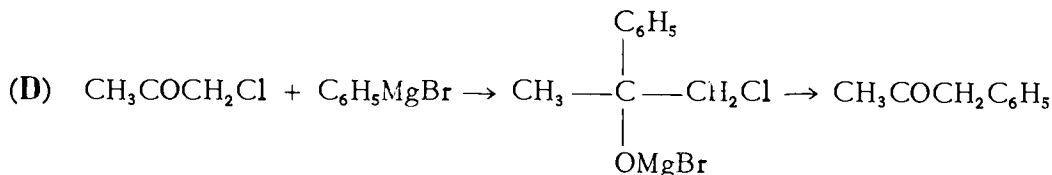
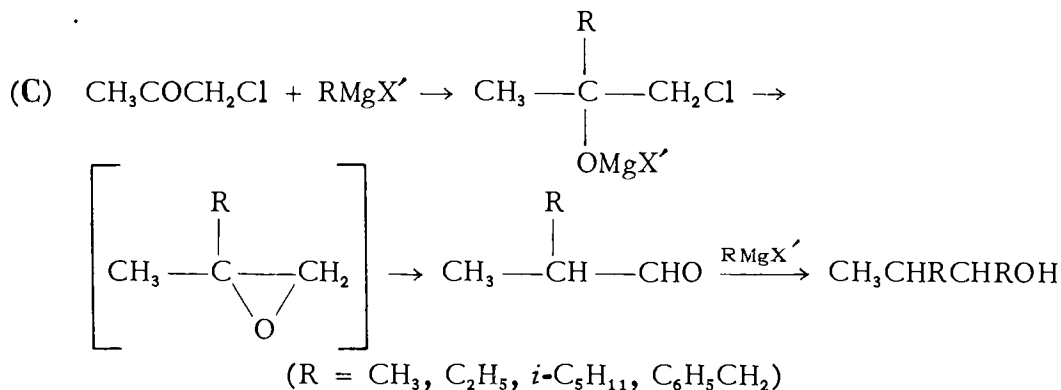
⁶²Geissman and Akawie, *J. Am. Chem. Soc.*, 73, 1993-8 (1951).



It is specified that in epoxide formation (B) expulsion of the X^- ion is probably facilitated by "solvation."

"Course A should be favored when the halogen atom is secondary or tertiary rather than primary; when the migrating R group can participate in the process and contribute to the resonance stabilization of the transition state; and when the relative disposition of X and OMgX' is [or can be] *cis*. Course B should be favored when X and OMgX' are *trans*; or, if these are or can be *cis*, when the halogen atom is primary and the migrating R group has a low migratory aptitude (*i.e.*, contributes little to resonance stabilization of the transition state).

"When the halogen atom is secondary or tertiary, course A seems always to be followed; but when it is primary the nature of the groups R and R' directs the course of the rearrangement, as illustrated by the examples C and D." [See Table VI-XVIII, $\text{C}_2\text{H}_5\text{OCl}$.]



Although the existing data (see Tables VI-XVIII, VI-XIX, and XVI-I) can scarcely be construed as constituting a critical confirmative test of the working hypothesis proposed, they are at least interpretable in complete consistency with it.

TABLE XVI-I
REACTIONS OF GRIGNARD REAGENTS WITH ALKYL, ARALKYL, AND CYCLOALKYL HALIDES

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CCl₄			
CCl ₄	C ₂ H ₅ MgBr (4 equiv.)	CH ₄ (1 part); C ₂ H ₄ (4 parts)	21
CCl ₄	C ₆ H ₅ MgBr	[(C ₆ H ₅) ₃ CO —] ₂ (30%); (C ₆ H ₅) ₃ COH (6%); [(C ₆ H ₅) ₃ C —] ₂	21
CHCl₃			
CHCl ₃	C ₂ H ₅ MgBr	CH ₄ ; C ₂ H ₄ ; traces of (C ₂ H ₅) ₃ CH and C ₂ H ₅ Br; (no C ₂ H ₂)	21
CHCl ₃ (10.3 g.)	C ₆ H ₅ MgBr (40.0 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ CH (70–80%, crude)	186
CHBr₃			
CHBr ₃	C ₂ H ₅ MgBr	CH ₂ Br ₂ ; CH ₃ Br; C ₂ H ₅ Br; CH ₄ ; C ₂ H ₄ ; C ₂ H ₆	163
CHBr ₃	C ₆ H ₅ MgBr	[(C ₆ H ₅) ₂ CH —] ₂ ; C ₆ H ₅ Br; [no (C ₆ H ₅) ₃ CH]	20
CHI₃			
CHI ₃	C ₂ H ₅ MgBr	CH ₂ I ₂ ; CH ₃ I; C ₂ H ₅ Br; C ₂ H ₅ I; CH ₄ ; C ₂ H ₂ ; C ₂ H ₆	163
CHI ₃	C ₆ H ₅ MgBr	[(C ₆ H ₅) ₂ CH —] ₂ ; (C ₆ H ₅ —) ₂ ; [no (C ₆ H ₅) ₃ CH]	163
CH₂I₂			
CH ₂ I ₂	C ₆ H ₅ C≡CMgBr	(C ₆ H ₅ C≡C) ₂ CH ₂ (8–10%)	88,89
CH₃I			
CH ₃ I	CH ₃ MgI	C ₂ H ₆ (> 51.6%)	212
CH ₃ I	CH ₃ MgI (excess)	C ₂ H ₃ (> 21%)	60
CH ₃ I	<i>t</i> -C ₄ H ₉ MgI	C(CH ₃) ₄ (15–20%)	55

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
CH₃I (cont.)			
CH ₃ I	<i>n</i> -C ₅ H ₁₁ C≡CMgBr	No reaction*	281
CH ₃ I	3-CH ₃ -5-CH ₃ OC ₆ H ₃ MgBr	1,3-(CH ₃) ₂ -5-CH ₃ OC ₆ H ₃	48
CH ₃ I	2-Methylindolyl-MgI	2,3-Dimethylindole; 1,3,3-trimethylindolenine	105
CH ₃ I	3-Methylindolyl-MgI	3,3-Dimethylindolenine (40%); 1,3-dimethylindole ("a little")	105
CH ₃ I (7.5 g.)	9-Anthryl-MgBr (2.57 g. C ₁₄ H ₉ Br)	9-Methylanthracene (0.80 g., 41%)	11
CH ₃ I	9-Phenanthryl-MgBr	9-Methylphenanthrene (73%)	9
CH ₃ I	(C ₆ H ₅) ₃ CMgBr	(C ₆ H ₅) ₃ CCH ₃ (98%)	10
CH ₃ I	(C ₆ H ₅) ₃ CMgBr	(C ₆ H ₅) ₃ CCH ₃ (93%)	10
C₂Cl₄			
C ₂ Cl ₄ (1 equiv.)	C ₂ H ₅ MgBr (4 equiv.)	C ₂ H ₂ ; C ₂ H ₄ ; C ₂ H ₆	22
C₂Cl₆			
C ₂ Cl ₆	RMgX	R ₂	190
C ₂ Cl ₆	C ₂ H ₅ MgBr	C ₂ H ₄ ; C ₂ H ₆ ; C ₂ HCl ₃ ; C ₂ Cl ₄ ; 1,1,1,2-Cl ₄ C ₂ H ₂ ; 1,1,2,2-Cl ₄ C ₂ H ₂	129,22
C ₂ Cl ₆	C ₆ H ₅ MgBr	C ₆ H ₆ ; (C ₆ H ₅ —) ₂ ; C ₂ HCl ₃ ; C ₂ Cl ₄ ; 1,1,1,2-Cl ₄ C ₂ H ₂ ; 1,1,2,2-Cl ₄ C ₂ H ₂	129
C ₂ Cl ₆	4-CH ₃ C ₆ H ₄ MgBr	CH ₃ C ₆ H ₅ ; (4-CH ₃ C ₆ H ₄ —) ₂ ; C ₂ HCl ₃ ; C ₂ Cl ₄ ; 1,1,1,2-Cl ₄ C ₂ H ₂ ; 1,1,2,2-Cl ₄ C ₂ H ₂	129
C ₂ Cl ₆	1-C ₁₀ H ₇ MgBr	C ₁₀ H ₈ ; (1-C ₁₀ H ₇ —) ₂ ; C ₂ HCl ₃ ; C ₂ Cl ₄ ; 1,1,1,2-Cl ₄ C ₂ H ₂ ; 1,1,2,2-Cl ₄ C ₂ H ₂	129

* Several weeks reflux in ethyl ethereal solution.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₂ClN			
NCCH ₂ Cl*	Indolyl-MgI (1 equiv.)	3-Indolylacetonitrile (<i>ca.</i> 47%) [†]	149
NCCH ₂ Cl* (1 equiv.)	Indolyl-MgI (7.8 g. C ₈ H ₇ N)	3-Indolylacetonitrile (5.3 g.) [†]	149
NCCH ₂ Cl* (6.1 g.)	6-Methoxyindolyl-MgI (11.7 g. C ₉ H ₉ NO)	6-Methoxy-3-indolylacetonitrile (7.4 g., 52%)	1
C₂H₂Cl₂O			
ClOCCH ₂ Cl [§] (28 g.)	C ₆ H ₅ MgBr (230 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ CHCH(OH)C ₆ H ₅ (36 g.); ClCH ₂ C(C ₆ H ₅) ₂ OH (0.3 g.)	26
C₂H₂Cl₂O₂			
HO ₂ CCHCl ₂ [†] (10 g.)	C ₆ H ₅ MgBr (73 g. C ₆ H ₅ Br)	HO(C ₆ H ₅) ₂ CCH(OH)C ₆ H ₅ (8.6 g.)	26
C₂H₂Cl₄			
(—CHCl ₂) ₂	C ₂ H ₅ MgBr (4 equiv.)	C ₂ H ₂ ; C ₂ H ₄ ; C ₂ H ₆	22
(—CHCl ₂) ₂	C ₆ H ₅ MgBr	(C ₆ H ₅ —) ₂ ; [(C ₆ H ₅) ₂ CH—] ₂	22
C₂H₃ClO₂			
HO ₂ CCH ₂ Cl [†]	1-C ₁₀ H ₇ MgBr (2 equiv.)	1-C ₁₀ H ₇ CH ₂ CO ₂ H	244

* It is altogether possible that this reaction has more in common with those of the α -halo ketones (*q.v.*, Chapter VI) than with those of the simple alkyl halides. See also α -Halo Nitriles, Chapter X.

[†] Reaction in Et₂O; two hours reflux.

[‡] Dropwise addition of anisole-halide solution to cold anisole-Grignard reagent solution; twenty minutes at 60–70°.

[§] It is altogether possible that this reaction has more in common with those of the α -halo ketones (*q.v.*, Chapter VI) than with those of the simple alkyl halides. See also α -Halo Carbonyl Halides, Chapter IX.

[†] It is altogether possible that this reaction has more in common with those of the α -halo ketones (*q.v.*, Chapter VI) than with those of the simple alkyl halides.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₂H₄ClBrMgO			
BrMgOCH ₂ CH ₂ Cl (42.0 g. C ₂ H ₅ ClO)	C ₆ H ₅ CH ₂ MgCl (126.0 g. C ₇ H ₇ Cl)	C ₆ H ₅ (CH ₂) ₃ OH (43.6 g., 64%)	266
BrMgOCH ₂ CH ₂ Cl	2,4-(CH ₃) ₂ C ₆ H ₃ MgBr	2,4-(CH ₃) ₂ C ₆ H ₃ CH ₂ CH ₂ OH	189
BrMgOCH ₂ CH ₂ Cl	2-C ₁₀ H ₇ MgBr	"Unsatisfactory"	258
C₂H₄Cl₂			
CH ₃ CHCl ₂	C ₂ H ₅ MgX*	C ₂ H ₂ ; C ₂ H ₄ ; C ₂ H ₆	22
C₂H₄Cl₂O			
O(CH ₂ Cl) ₂	(≡CMgX) ₂	1,6-Dioxacyclodeca-3,8-diyne	139
O(CH ₂ Cl) ₂ (22.8 g.)	C ₂ H ₅ MgBr (21.8 g. C ₂ H ₅ Br) + C ₆ H ₅ MgBr (31.0 g. C ₆ H ₅ Br)	<i>n</i> -C ₃ H ₇ OCH ₂ C ₆ H ₅ (45-50%)	249
O(CH ₂ Cl) ₂ (0.5 mole)	C ₆ H ₅ MgBr (1.0 mole C ₆ H ₅ Br)	(C ₆ H ₅ CH ₂) ₂ O (<i>ca.</i> 90%, crude; 56%, pure)	249
O(CH ₂ Cl) ₂	C ₆ H ₅ CH ₂ MgCl	(C ₆ H ₅ CH ₂ CH ₂) ₂ O (<i>ca.</i> 80%, crude; 40-44%, pure)	249
O(CH ₂ Cl) ₂	4-CH ₃ C ₆ H ₄ MgBr	(4-CH ₃ C ₆ H ₄ CH ₂) ₂ O (61%)	249
O(CH ₂ Cl) ₂	1-C ₁₀ H ₇ MgBr	(1-C ₁₀ H ₇ CH ₂) ₂ O (35-40%)	249
C₂H₄Br₂O			
O(CH ₂ Br) ₂ (20.4 g.)	<i>i</i> -C ₄ H ₉ MgBr (27.4 g. C ₄ H ₉ Br)	(<i>i</i> -C ₅ H ₁₁) ₂ O (80%, crude; 25%, pure)	249
O(CH ₂ Br) ₂ (0.5 mole)	C ₆ H ₅ MgBr (1.0 mole C ₆ H ₅ Br)	(C ₆ H ₅ CH ₂) ₂ O (<i>ca.</i> 90%, crude; 56%, pure)	249
C₂H₅ClO			
HOCH ₂ CH ₂ Cl	C ₆ H ₅ MgCl	C ₆ H ₅ CH ₂ CH ₂ OH (53%)	260
HOCH ₂ CH ₂ Cl	ArMgBr [†]	ArCH ₂ CH ₂ OH [†] (<i>ca.</i> 80%)	86,87,211, 271, 272

* X = Cl, Br.

† Ar = C₆H₅, 2-CH₃C₆H₄, 4-CH₃C₆H₄, 4-CH₃OC₆H₄, 1-C₁₀H₇.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₂H₅ClO (cont.)			
HOCH ₂ CH ₂ Cl	ArMgBr*	ArCH ₂ CH ₂ OH*	18
HOCH ₂ CH ₂ Cl	ArMgBr [†]	ArCH ₂ CH ₂ OH [†] (20-24%)	206
HOCH ₂ CH ₂ Cl	ArCH ₂ MgCl [‡]	Ar(CH ₂) ₃ OH [‡]	18
HOCH ₂ CH ₂ Cl	C ₆ H ₅ O(CH ₂) ₅ MgI	C ₆ H ₅ O(CH ₂) ₇ OH	227
HOCH ₂ CH ₂ Cl (22.4 ml.)	9-Phenanthryl-MgBr (48.5 g. C ₁₄ H ₉ Br)	C ₁₄ H ₉ CH ₂ CH ₂ OH (40-50 g.)	262
CH ₃ OCH ₂ Cl	(≡CMgBr) ₂	(≡CCH ₂ OCH ₃) ₂	49,134, 143
CH ₃ OCH ₂ Cl	H ₂ C=CBrCH ₂ CH ₂ MgBr	H ₂ C=CBr(CH ₂) ₃ OCH ₃	142
CH ₃ OCH ₂ Cl	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₅ H ₁₁ OCH ₃ (67%)	84
CH ₃ OCH ₂ Cl	H ₂ C(CH ₂ CH ₂ MgBr) ₂	CH ₃ O(CH ₂) ₇ OCH ₃ (45%)	47
CH ₃ OCH ₂ Cl	Br(CH ₂) ₅ Br + Mg	CH ₃ O(CH ₂) ₅ CH ₃ ; CH ₃ O(CH ₂) ₇ OCH ₃ ; CH ₃ O(CH ₂) ₁₂ OCH ₃ ; high-boiling products	
CH ₃ OCH ₂ Cl	(—CH ₂ C≡CMgBr) ₂	(—CH ₂ C≡CCH ₂ OCH ₃) ₂	134
CH ₃ OCH ₂ Cl (0.1 mole)	C ₆ H ₅ CH ₂ MgCl (0.1 mole C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CH ₂ OCH ₃ (88x%); 2-CH ₃ C ₆ H ₄ CH ₂ OCH ₃ (5x%); 4-CH ₃ C ₆ H ₄ CH ₂ OCH ₃ (7x%)	263
CH ₃ OCH ₂ Cl (0.1 mole)	C ₆ H ₅ CH ₂ MgBr (0.1 mole C ₇ H ₇ Br)	C ₆ H ₅ CH ₂ CH ₂ OCH ₃ (79x%); 2-CH ₃ C ₆ H ₄ CH ₂ OCH ₃ (13x%); 4-CH ₃ C ₆ H ₄ CH ₂ OCH ₃ (8x%)	263
CH ₃ OCH ₂ Cl (0.1 mole)	C ₆ H ₅ CH ₂ MgI (0.1 mole C ₇ H ₇ I)	C ₆ H ₅ CH ₂ CH ₂ OCH ₃ (84x%); 2-CH ₃ C ₆ H ₄ CH ₂ OCH ₃ (7x%); 4-CH ₃ C ₆ H ₄ CH ₂ OCH ₃ (9x%)	263
CH ₃ OCH ₂ Cl	2-CH ₃ C ₆ H ₄ CH ₂ MgBr	2,3-(CH ₃) ₂ C ₆ H ₃ CH ₂ OCH ₃ (90x%)	270

* Ar = C₆H₅, 2-CH₃C₆H₄, 4-CH₃C₆H₄, 2,4-(CH₃)₂C₆H₃, 2,5-(CH₃)₂C₆H₃, 4-*i*-C₃H₇C₆H₄, 2-CH₃-5-*i*-C₃H₇C₆H₃.

[†] Ar = 2-CH₃C₆H₄, 3-CH₃C₆H₄, 4-CH₃C₆H₄.

[‡] Ar = C₆H₅, 4-CH₃C₆H₄, 2,4-(CH₃)₂C₆H₃, 2,5-(CH₃)₂C₆H₃, 4-*i*-C₃H₇C₆H₄, 2-CH₃-4-*i*-C₃H₇C₆H₃, 4-C₂H₅C₆H₄, 4-*n*-C₃H₇C₆H₄, 4-*n*-C₄H₉C₆H₄, 4-*t*-C₄H₉C₆H₄, 4-*t*-C₅H₁₁C₆H₄, 2,4,5-(CH₃)₃C₆H₂, 2-CH₃-5-*i*-C₃H₇C₆H₃.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₅ClO (cont.)			
CH ₃ OCH ₂ Cl	3-CH ₃ C ₆ H ₄ CH ₂ MgBr	3-CH ₃ C ₆ H ₄ (CH ₂) ₂ OCH ₃	270
CH ₃ OCH ₂ Cl	4-CH ₃ C ₆ H ₄ CH ₂ MgBr	4-CH ₃ C ₆ H ₄ (CH ₂) ₂ OCH ₃ (80x%); 2,5-(CH ₃) ₂ C ₆ H ₃ CH ₂ OCH ₃ (20x%)	270
CH ₃ OCH ₂ Cl (15.0 g.)	R(CH ₂) ₂ CH(CH ₃)(CH ₂) ₂ MgBr* (40.0 g. C ₁₅ H ₂₉ Br)	[R(CH ₂) ₂ CH(CH ₃)(CH ₂) ₂ —] ₂ * (6.8 g., crude); R(CH ₂) ₂ CH(CH ₃)(CH ₂) ₃ OCH ₃ * (11.5 g., crude)	116
CH ₃ OCH ₂ Cl	(C ₆ H ₅) ₃ CMgBr	(C ₆ H ₅) ₃ CCH ₂ OCH ₃ (70%)	10
C₂H₅Br			
C ₂ H ₅ Br	(≡CMgBr) ₂	(≡CC ₂ H ₅) ₂ (20%)	219
C ₂ H ₅ Br	C ₂ H ₅ MgBr	C ₂ H ₄ + C ₂ H ₆ (in equimol. prop'n)	212
C ₂ H ₅ Br	C ₆ H ₅ MgBr + FeCl ₃ (trace)	C ₂ H ₅ C ₆ H ₅ (50-60%)	282,225
C ₂ H ₅ Br	4-CH ₃ OC ₆ H ₄ MgBr + FeCl ₃ (trace)	C ₂ H ₅ C ₆ H ₄ -4-OCH ₃ (50-60%)	282,225
C ₂ H ₅ Br	(CH ₃) ₅ C ₆ MgCl	(CH ₃) ₅ C ₆ C ₂ H ₅ (40%)	37
C ₂ H ₅ Br (0.2 mole)	(CH ₃) ₅ C ₆ Br (0.2 mole) + Mg (10 g.)	(CH ₃) ₅ C ₆ C ₂ H ₅ (19 g.); (CH ₃) ₅ C ₆ H (2 g.)	192
C ₂ H ₅ Br	9-Anthryl-MgBr + FeCl ₃ (trace)	9-Ethylanthracene (50-60%)	282
C ₂ H ₅ Br	(C ₆ H ₅) ₃ CMgBr	(C ₆ H ₅) ₃ CC ₂ H ₅ (73%)	10
C₂H₅BrO			
HOCH ₂ CH ₂ Br (650 g., 5.2 moles)	<i>n</i> -C ₄ H ₉ MgBr (1,430 g., 10.42 moles C ₄ H ₉ Br)	<i>n</i> -C ₆ H ₁₃ OH (268 g., 50.6%); CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (30 g.) [†]	39 39
HOCH ₂ CH ₂ Br (5 moles)	<i>n</i> -C ₄ H ₉ MgBr (10 moles C ₄ H ₉ Br)	<i>n</i> -C ₆ H ₁₃ OH (184 g., 38%); CH ₃ (<i>n</i> -C ₄ H ₉)CHOH (54.6 g.) [†]	39

* R = 2,2,6-trimethylcyclohexyl.

[†] Dropwise addition of bromohydrin to ethereal Grignard reagent solution; five hours reflux.[‡] One and one-half hour reflux at 35°; partial replacement of ether by benzene; heating to 65°.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₅BrO (<i>cont.</i>)			
CH ₃ OCH ₂ Br	CH ₃ OCH ₂ MgBr	(—CH ₂ OCH ₃) ₂	95
CH ₃ OCH ₂ Br	C ₆ H ₅ MgBr	CH ₃ OCH ₂ C ₆ H ₅ (< 60–65%)	94
CH ₃ OCH ₂ Br	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ CH ₂ OCH ₃ (< 60–65%)	94
CH ₃ OCH ₂ Br (0.1 mole)	C ₆ H ₅ CH ₂ MgCl (0.1 mole C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CH ₂ OCH ₃ (78x–79x%); 2-CH ₃ C ₆ H ₄ CH ₂ OCH ₃ (12x–14x%); 4-CH ₃ C ₆ H ₄ CH ₂ OCH ₃ (7x–10x%)	263
C₂H₅I			
C ₂ H ₅ I	<i>n</i> -C ₃ H ₇ MgI	Alkenes, comprising 47.1% C ₂ H ₄ , 52.9% C ₃ H ₆ ; alkanes, comprising C ₂ H ₆ , C ₃ H ₈ , and traces of <i>n</i> -C ₄ H ₁₀ and <i>n</i> -C ₅ H ₁₂	212
C₂H₅IO			
CH ₃ OCH ₂ I (0.1 mole)	C ₆ H ₅ CH ₂ MgCl (0.1 mole C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CH ₂ OCH ₃ (88x%); 2-CH ₃ C ₆ H ₄ CH ₂ OCH ₃ (6x%); 4-CH ₃ C ₆ H ₄ CH ₂ OCH ₃ (6x%)	263
C₃Cl₃N₃			
Cyanuric chloride*	C ₆ H ₅ MgBr	2-Chloro-4,6-diphenyl-1,3,5-triazine; 2,4-dichloro-6-phenyl-1,3,5-triazine	276
C₃Br₃N₃			
Cyanuric bromide [†] (7.5 g.)	C ₂ H ₅ MgI (15.5 g. C ₂ H ₅ I)	2,4,6-Triethyl-1,3,5-triazine (yielding C ₂ H ₅ CO ₂ H upon hydrolysis)	277

* 2,4,6-Trichloro-1,3,5-triazine. Although this reaction has the formal appearance of that of a simple cycloalkyl halide, it is probably nothing of the sort.

[†] 2,4,6-Tribromo-1,3,5-triazine.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃HCl₅			
C ₃ HCl ₅ (b.p. 70–71°/12.5 mm.) (1 equiv.)	CH ₃ MgI (1 equiv.)	C ₂ H ₆ ; Cl ₂ C=CHCl (?)	183
C₃HCl₇			
C ₃ HCl ₇ (30 g.)	CH ₃ MgI (35.5 g. CH ₃ I)	CH ₄ (equiv. to 1 active H); C ₃ HCl ₅	182
C ₃ HCl ₇ (23 g.)	CH ₃ MgI (3 equiv.)	C ₃ HCl ₅ , b.p. 70–71°/12.5 mm. (10.7 g.); CH ₄ ; C ₂ H ₆ ; high-boiling products	182, 183, 29
C ₃ HCl ₇	C ₂ H ₅ MgI	n-C ₄ H ₁₀ ; C ₃ HCl (?)	183
C₃H₃Br			
HC≡CCH ₂ Br	RMgX	"Complex products"*	284
HC≡CCH ₂ Br	RMgX	H ₂ C≡CCH ₂ R (chiefly); H ₂ C=C=CH ₂ R [†]	284
C₃H₄ClF₃			
F ₃ CCH ₂ CH ₂ Cl	C ₂ H ₅ MgBr	No reaction	99
C₃H₄ClN			
NCCH ₂ CH ₂ Cl (13.8 g.)	Indolyl-MgI (18.0 g. C ₈ H ₇ N)	3-β-Indolylpropionitrile (16.8 g.)	149
C₃H₄Cl₂			
H ₂ C=CHCHCl ₂	CH ₃ MgBr	CH ₄ ; C ₂ H ₆ ; C ₂ H ₅ CH=CHCl; C ₂ H ₅ CH=CHCH ₃ ; H ₂ C=CHCH(CH ₃) ₂ ; CH ₃ (H ₂ CCH=CH) ₂ CH ₃ ; high-boiling hydrocarbons	290

* At the boiling point of ethyl ethereal solution.

[†] At -15°.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₃H₄Cl₂ (cont.)			
H ₂ C=CHCHCl ₂	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₄ H ₉ CH=CHCl (<i>ca.</i> 25%); <i>n</i> -C ₃ H ₇ CH=CH- <i>n</i> -C ₄ H ₉ ; C ₁₂ H ₂₂ (30%); C ₆ H ₁₄	291
H ₂ C=CHCHCl ₂	<i>i</i> -C ₃ H ₇ MgBr	C ₃ H ₈ ; C ₆ H ₁₄ ; <i>i</i> -C ₄ H ₉ CH=CHCl; <i>i</i> -C ₄ H ₉ CH=CH- <i>i</i> -C ₃ H ₇ ; H ₂ C=CHCH- (<i>i</i> -C ₃ H ₇) ₂ ; <i>i</i> -C ₃ H ₇ (H ₂ CCH=CH) ₂ - <i>i</i> -C ₃ H ₇ ; high-boiling hydrocarbons	290
H ₂ C=CHCHCl ₂	<i>n</i> -C ₄ H ₉ MgBr	C ₄ H ₁₀ ; C ₈ H ₁₈ ; <i>n</i> -C ₅ H ₁₁ CH=CHCl; <i>n</i> -C ₅ H ₁₁ CH=CH- <i>n</i> -C ₄ H ₉ ; H ₂ C=CHCH- (<i>n</i> -C ₄ H ₉) ₂ ; <i>n</i> -C ₄ H ₉ (H ₂ CCH=CH) ₂ - <i>n</i> -C ₄ H ₉ ; high-boiling hydrocarbons	290
H ₂ C=CHCHCl ₂	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ CH=CHCl ("poor yield"); considerable tar	126
ClCH=CHCH ₂ Cl	CH ₃ MgBr	CH ₄ ; C ₂ H ₆ ; C ₂ H ₅ CH=CHCl; C ₂ H ₅ CH=CHCH ₃ ; H ₂ C=CHCH(CH ₃) ₂ ; CH ₃ -(H ₂ CCH=CH) ₂ CH ₃ ; high-boiling hydrocarbons	290
ClCH=CHCH ₂ Cl	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₄ H ₉ CH=CHCl ("very little"); C ₆ H ₁₄ ; <i>n</i> -C ₃ H ₇ CH=CH- <i>n</i> -C ₄ H ₉ ; C ₁₂ H ₂₂ (30%)	291
ClCH=CHCH ₂ Cl	<i>i</i> -C ₃ H ₇ MgBr	C ₃ H ₈ ; C ₆ H ₁₄ ; <i>i</i> -C ₄ H ₉ CH=CHCl; <i>i</i> -C ₄ H ₉ CH=CH- <i>i</i> -C ₃ H ₇ ; H ₂ C=CHCH(<i>i</i> -C ₃ H ₇) ₂ ; <i>i</i> -C ₃ H ₇ (H ₂ CCH=CH) ₂ - <i>i</i> -C ₃ H ₇ ; high-boiling hydrocarbons	290
ClCH=CHCH ₂ Cl	<i>n</i> -C ₄ H ₉ MgBr	C ₄ H ₁₀ ; C ₈ H ₁₈ ; <i>n</i> -C ₅ H ₁₁ CH=CHCl; <i>n</i> -C ₅ H ₁₁ CH=CH- <i>n</i> -C ₄ H ₉ ; H ₂ C=CHCH(<i>n</i> -C ₄ H ₉) ₂ ; <i>n</i> -C ₄ H ₉ (H ₂ CCH=CH) ₂ - <i>n</i> -C ₄ H ₉ ; high-boiling hydrocarbons	290

TABLE XVI-I (Continued)

Halides	RMgX	Product(s)	Ref.
C₃H₄Cl₂ (cont)			
ClCH=CHCH ₂ Cl	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ CH ₂ CH=CHCl ("high yield")	17
ClCH=CHCH ₂ Cl	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ CH=CHCl (<i>ca.</i> quant.)	17
ClCH=CHCH ₂ Cl	2-CH ₃ C ₆ H ₄ MgBr	2-CH ₃ C ₆ H ₅ CH ₂ CH=CHCl ("high yield")	17
ClCH=CHCH ₂ Cl	4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ CH ₂ CH=CHCl ("high yield")	17
ClCH=CHCH ₂ Cl	4-CH ₃ OC ₆ H ₄ MgBr	4-CH ₃ OC ₆ H ₄ CH ₂ CH=CHCl ("high yield")	17
ClCH=CHCH ₂ Cl	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ MgBr	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ CH=CHCl ("high yield")	17
ClCH=CHCH ₂ Cl	2-CH ₃ -5- <i>i</i> -C ₃ H ₇ C ₆ H ₃ MgBr	2-CH ₃ -5- <i>i</i> -C ₃ H ₇ C ₆ H ₃ CH ₂ CH=CHCl ("high yield")	17
C₃H₄Br₂			
H ₂ C=CBrCH ₂ Br	CH ₃ MgBr	H ₂ C=CBrC ₂ H ₅	140,124
H ₂ C=CBrCH ₂ Br	C ₂ H ₅ MgBr	H ₂ C=CBr- <i>n</i> -C ₃ H ₇	135,25
H ₂ C=CBrCH ₂ Br	<i>n</i> -C ₃ H ₇ MgBr	H ₂ C=CBr- <i>n</i> -C ₄ H ₉	25
H ₂ C=CBrCH ₂ Br	<i>i</i> -C ₃ H ₇ MgBr	H ₂ C=CBr- <i>i</i> -C ₄ H ₉	136
H ₂ C=CBrCH ₂ Br	<i>n</i> -C ₄ H ₉ MgBr	H ₂ C=CBr- <i>n</i> -C ₅ H ₁₁	124
H ₂ C=CBrCH ₂ Br	<i>t</i> -C ₄ H ₉ MgCl	H ₂ C=CBrCH ₂ - <i>t</i> -C ₄ H ₉ (45-62%)	165
H ₂ C=CBrCH ₂ Br	C ₆ H ₅ MgBr	H ₂ C=CBrCH ₂ C ₆ H ₅	136,25
H ₂ C=CBrCH ₂ Br	(CH ₂) ₅ CHMgBr	H ₂ C=CBrCH ₂ CH(CH ₂) ₅	136,25
H ₂ C=CBrCH ₂ Br	H ₂ C[(CH ₂) ₃ MgBr] ₂	[H ₂ C=CBr(CH ₂) ₄] ₂ CH ₂ ; [H ₂ C=CBr(CH ₂) ₈ —] ₂	137
BrCH=CHCH ₂ Br	CH ₃ MgBr	CH ₄ ; C ₂ H ₆ (<i>ca.</i> 3%); (H ₂ C=CH—) ₂ (5%); "bromobutene," b. 92-94°; "octadiene," b. 118-120°; C ₁₀ H ₁₈ (?), b ₁₂ 70-80°	283,291
BrCH=CHCH ₂ Br	C ₂ H ₅ MgBr (excess)	"Heptene," b. 94-96° (30%)	283,291
BrCH=CHCH ₂ Br (excess)	C ₂ H ₅ MgBr	BrCH=CH- <i>n</i> -C ₃ H ₈	283,291
BrCH=CHCH ₂ Br	<i>n</i> -C ₃ H ₇ MgBr	C ₆ H ₁₄ (5%); <i>n</i> -C ₃ H ₇ CH=CH- <i>n</i> -C ₄ H ₉ (47%); C ₁₂ H ₂₂ , b ₁₃ 83-88°	283,291

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₄Br₂ (cont).			
BrCH=CHCH ₂ Br	C ₆ H ₅ MgBr	BrCH=CHCH ₂ C ₆ H ₅ (50%)	291,292
C₃H₄ICl			
ClCH=CHCH ₂ I	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₄ H ₉ CH=CHCl (?)*; unidentified products	126
C₃H₅Cl			
H ₂ C=CHCH ₂ Cl (153 g.)	C ₂ H ₅ MgBr (240 g. C ₂ H ₅ Br)	H ₂ C=CH- <i>n</i> -C ₃ H ₇ (40-50%)	117
H ₂ C=CHCH ₂ Cl (153 g.)	<i>n</i> -C ₃ H ₇ MgBr (246 g. C ₃ H ₇ Br)	H ₂ C=CH- <i>n</i> -C ₄ H ₉ (40-50%)	117
H ₂ C=CHCH ₂ Cl	Butenyl-MgBr (<i>ca.</i> 1 equiv.)	(H ₂ C=CHCH ₂) ₂ CH ₂ (< 4%); H ₂ C=CHCH(CH ₃)CH ₂ CH=CH ₂ (> 48%)	245
H ₂ C=CHCH ₂ Cl (153 g.)	<i>n</i> -C ₄ H ₉ MgBr (275 g. C ₄ H ₉ Br)	H ₂ C=CH- <i>n</i> -C ₅ H ₁₁ (47%)	117
H ₂ C=CHCH ₂ Cl	<i>n</i> -C ₅ H ₁₁ MgCl	H ₂ C=CH- <i>n</i> -C ₆ H ₁₃ (80%)	98,38
H ₂ C=CHCH ₂ Cl	<i>i</i> -C ₅ H ₁₁ MgCl	H ₂ C=CH- <i>i</i> -C ₆ H ₁₃ (60%)	98
H ₂ C=CHCH ₂ Cl	C ₆ H ₅ MgBr	H ₂ C=CHCH ₂ C ₆ H ₅ (<i>ca.</i> 82%)	103
H ₂ C=CHCH ₂ Cl (76.5 g.)	<i>n</i> -C ₈ H ₁₇ MgBr (193.0 g. C ₈ H ₁₇ Br)	H ₂ C=CH- <i>n</i> -C ₉ H ₁₉ (51%)	117
C₃H₅ClBr₂MgO			
BrCH ₂ CH(OMgBr)CH ₂ [†]	C ₂ H ₅ MgBr	(CH ₂) ₂ CHOH; ClCH ₂ CH(OH)CH ₂ Br (13-53%); tar; C ₂ H ₄ ; C ₂ H ₆	148
C₃H₅Br			
H ₂ C=CHCH ₂ Br	C ¹⁴ H ₃ MgI	H ₂ C=CHCH ₂ C ¹⁴ H ₃ (63%)	185
H ₂ C=CHCH ₂ Br	HC≡CMgBr	H ₂ C=CHCH ₂ C≡CH (75%)	90,196

* Not positively identified; small yield if any.

[†] From α -epichlorohydrin + MgBr₂ (expts. 1-6) or ClCH₂CH(OH)CH₂Br + C₂H₅MgBr (expts. 7-11).

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₃H₅Br (cont.)			
H ₂ C=CHCH ₂ Br	C ₂ H ₅ MgBr	H ₂ C=CH- <i>n</i> -C ₃ H ₇ (94%)	123,112, 53,242 133
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₃ H ₇ MgBr	H ₂ C=CH- <i>n</i> -C ₄ H ₉ (77%)	242,27
H ₂ C=CHCH ₂ Br	H ₂ C=CHC≡CMgBr + CuCl	H ₂ C=CHC≡CCH ₂ CH=CH ₂ ("high yield")	43
H ₂ C=CHCH ₂ Br	Pyrryl-MgBr	2-Allylpyrrole + 2,5-diallylpyrrole (ca. equal parts)	250
H ₂ C=CHCH ₂ Br (86.5 g.)	Butenyl-MgBr (141.0 g. C ₄ H ₇ Br)	H ₂ C=CHCH(CH ₃)CH ₂ CH=CH ₂ (34.6 g., 50%)	147
H ₂ C=CHCH ₂ Br (10-15% excess)	Butenyl-MgBr (0.6 mole)	(H ₂ C=CHCH ₂) ₂ CH ₂ (34%); H ₂ C=CHCH(CH ₃)CH ₂ CH=CH ₂ (34%)	245
H ₂ C=CHCH ₂ Br (67 g.)	3-Tetrahydrofuryl-MgBr (75 g. C ₄ H ₇ BrO)	H ₂ C=CHCH ₂ CH ₂ OH (6 g.); 3-allyl- tetrahydrofuran (3.5 g.); recovered starting material (40 g.).	246
H ₂ C=CHCH ₂ Br	(—CH ₂ CH ₂ Mgl) ₂	[—(CH ₂) ₃ CH=CH ₂] ₂	227
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₄ H ₉ MgBr	H ₂ C=CH- <i>n</i> -C ₅ H ₁₁ (90%)	242,232
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₄ H ₉ MgBr	C ₇ H ₁₄ (b.p. 88.0-88.5°); C ₇ H ₁₄ (b.p. 90.5-90.8°). (Total heptenes, 59%)	103
H ₂ C=CHCH ₂ Br	<i>i</i> -C ₄ H ₉ MgBr	H ₂ C=CH- <i>i</i> -C ₅ H ₁₁ (21%)	160,27, 227
H ₂ C=CHCH ₂ Br	<i>t</i> -C ₄ H ₉ MgCl	H ₂ C=CH- <i>t</i> -C ₄ H ₉ (85%)	238,160
H ₂ C=CHCH ₂ Br (745 g.)	(CH ₂) ₄ CHMgBr (915 g. C ₅ H ₉ Br)	H ₂ C=CHCH ₂ CH(CH ₂) ₄ (510 g., 75%)	237
H ₂ C=CHCH ₂ Br	Br(CH ₂) ₅ Br + Mg	[H ₂ C=CH(CH ₂) ₃] ₂ CH ₂ ; [H ₂ C=CH(CH ₂) ₆ —] ₂	184
H ₂ C=CHCH ₂ Br	H ₂ C(CH ₂ CH ₂ Mgl) ₂	[H ₂ C=CH(CH ₂) ₃] ₂ CH ₂	227
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₅ H ₁₁ MgBr	H ₂ C=CH- <i>n</i> -C ₆ H ₁₃ (89%)	242,123, 233

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₃H₅Br (cont.)			
H ₂ C=CHCH ₂ Br	<i>i</i> -C ₅ H ₁₁ MgBr	H ₂ C=CH- <i>i</i> -C ₆ H ₁₃ ("good yield"); "a decane"	227
H ₂ C=CHCH ₂ Br	<i>s</i> -C ₄ H ₉ CH ₂ MgBr*	H ₂ C=CHCH ₂ CH ₂ - <i>s</i> -C ₄ H ₉	226
H ₂ C=CHCH ₂ Br	4-BrC ₆ H ₄ MgBr	H ₂ C=CHCH ₂ C ₆ H ₄ -4-Br (70%)	176
H ₂ C=CHCH ₂ Br	C ₆ H ₅ MgBr	H ₂ C=CHCH ₂ C ₆ H ₅ (86-88%)	147,103, 221
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₄ H ₉ C≡CMgBr	No reaction†	43
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₄ H ₉ C≡CMgBr + CuCl†	H ₂ C=CHCH ₂ C≡C- <i>n</i> -C ₄ H ₉ (88%)	43
H ₂ C=CHCH ₂ Br	(CH ₂) ₅ CHMgBr	H ₂ C=CHCH ₂ CH(CH ₂) ₅ (42%)	227
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₆ H ₁₃ MgBr	H ₂ C=CH- <i>n</i> -C ₇ H ₁₅ (85%)	242,200
H ₂ C=CHCH ₂ Br	4-BrC ₆ H ₄ CH ₂ MgCl	H ₂ C=CH(CH ₂) ₂ C ₆ H ₄ -4-Br (70%)	178,177
H ₂ C=CHCH ₂ Br	C ₆ H ₅ CH ₂ MgCl	H ₂ C=CH(CH ₂) ₂ C ₆ H ₅	23
H ₂ C=CHCH ₂ Br	C ₆ H ₅ CH ₂ MgBr	H ₂ C=CH(CH ₂) ₂ C ₆ H ₅ (77%)	130
H ₂ C=CHCH ₂ Br (40 g.)	2-CH ₃ C ₆ H ₄ MgBr (56 g. C ₇ H ₇ Br)	H ₂ C=CHCH ₂ C ₆ H ₄ -2-CH ₃ (70%)	108
H ₂ C=CHCH ₂ Br	2-CH ₃ C ₆ H ₄ MgI	H ₂ C=CHCH ₂ C ₆ H ₄ -2-CH ₃ (65%)	104
H ₂ C=CHCH ₂ Br (120 g.)	4-CH ₃ C ₆ H ₄ MgBr (168 g. C ₇ H ₇ Br)	H ₂ C=CHCH ₂ C ₆ H ₄ -4-CH ₃ (97 g., 75%); (4-CH ₃ C ₆ H ₄ -) ₂ (4 g.)	108
H ₂ C=CHCH ₂ Br (121 g., 1 mole)	4-CH ₃ OC ₆ H ₄ MgBr (187 g., 1 mole C ₇ H ₇ BrO)	H ₂ C=CHCH ₂ C ₆ H ₄ -4-OCH ₃ (120 g., 81%)	278,221
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₅ H ₁₁ C≡CMgBr	H ₂ C=CHCH ₂ C≡C- <i>n</i> -C ₅ H ₁₁	89

* From D(-)-2-methyl-1-butanol.

† No reaction took place in ether with intermittent stirring at room temperature for twenty-three days; refluxing in benzene or *n*-amyl ether for two to twelve hours was also ineffective. This behavior was common to the 1-alkynylmagnesium halides in general.

‡ With 2 g. of catalyst per mole of Grignard reagent, reaction proceeded in ether solution at room temperature. Cuprous bromide and cuprous cyanide were also effective, as were the cupric halides (which are immediately reduced to the cuprous compounds by most Grignard reagents); copper bronze proved ineffective.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₃H₅Br (cont.)			
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₅ H ₁₁ C≡CMgBr + CuCl	H ₂ C=CHCH ₂ C≡C- <i>n</i> -C ₅ H ₁₁ ("high yield")	43
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₇ H ₁₅ MgX	H ₂ C=CH- <i>n</i> -C ₈ H ₁₇ (ca. 50%)	200
H ₂ C=CHCH ₂ Br	C ₆ H ₅ C≡CMgBr	H ₂ C=CHCH ₂ C≡CC ₆ H ₅ (70%)	88,89
H ₂ C=CHCH ₂ Br	C ₆ H ₅ C≡CMgBr + CuCl	H ₂ C=CHCH ₂ C≡CC ₆ H ₅ ("high yield")	43
H ₂ C=CHCH ₂ Br	C ₆ H ₅ CH ₂ CH ₂ MgBr	H ₂ C=CH(CH ₂) ₃ C ₆ H ₅ (70%)	227
H ₂ C=CHCH ₂ Br	4-C ₂ H ₅ OC ₆ H ₄ MgBr	H ₂ C=CHCH ₂ C ₆ H ₄ -4-OC ₂ H ₅ (66.5%)	279
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₈ H ₁₇ MgX	H ₂ C=CH- <i>n</i> -C ₉ H ₁₉ (65%); C ₁₆ H ₃₄	227,200
H ₂ C=CHCH ₂ Br	C ₆ H ₅ (CH ₂) ₃ MgBr	H ₂ C=CH(CH ₂) ₄ C ₆ H ₅ (87%)	130,227
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₉ H ₁₉ MgX	H ₂ C=CH- <i>n</i> -C ₁₀ H ₂₁ (ca. 50%)	200
H ₂ C=CHCH ₂ Br	C ₆ H ₅ O(CH ₂) ₄ MgI	H ₂ C=CH(CH ₂) ₅ OC ₆ H ₅ (50%)	227
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₁₀ H ₂₁ MgBr	H ₂ C=CH- <i>n</i> -C ₁₁ H ₂₃ (77%)	130,200
H ₂ C=CHCH ₂ Br	C ₆ H ₅ (CH ₂) ₅ MgBr	H ₂ C=CH(CH ₂) ₆ C ₆ H ₅ (55%)	227
H ₂ C=CHCH ₂ Br	(CH ₃) ₅ C ₆ MgCl	H ₂ C=CHCH ₂ C ₆ (CH ₃) ₅ (40-50%)	37
H ₂ C=CHCH ₂ Br	(CH ₃) ₅ C ₆ Br + Mg	H ₂ C=CHCH ₂ C ₆ (CH ₃) ₅	192
H ₂ C=CHCH ₂ Br	C ₆ H ₅ O(CH ₂) ₅ MgI	H ₂ C=CH(CH ₂) ₆ OC ₆ H ₅ (ca. 50%)	227
H ₂ C=CHCH ₂ Br (19.7 g.)	2-C ₆ H ₅ C ₆ H ₄ MgBr (32.0 g. C ₁₂ H ₉ Br)	H ₂ C=CHCH ₂ C ₆ H ₄ -2-C ₆ H ₅ (16.0 g., 60%)	259
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₁₂ H ₂₅ MgBr	H ₂ C=CH- <i>n</i> -C ₁₃ H ₂₇ (67%)	130,200
H ₂ C=CHCH ₂ Br	2-Methoxy-1-dibenzofuryl-MgBr	1-Allyl-2-methoxydibenzofuran (74%)	73
H ₂ C=CHCH ₂ Br	2-Methoxy-3-dibenzofuryl-MgBr	2-Methoxy-3-allyldibenzofuran (60%)	73
H ₂ C=CHCH ₂ Br (12.1 g.)	9-Phenanthryl-MgBr (25.7 ml. C ₁₄ H ₉ Br)	9-Allylphenanthrene (13.0 g.)	13
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₁₄ H ₂₉ MgBr	H ₂ C=CH- <i>n</i> -C ₁₅ H ₃₁ (43%)	130,200
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₁₆ H ₃₃ MgBr	H ₂ C=CH- <i>n</i> -C ₁₇ H ₃₅ (56%)	130
H ₂ C=CHCH ₂ Br	<i>n</i> -C ₁₈ H ₃₇ MgX	H ₂ C=CH- <i>n</i> -C ₁₉ H ₃₉ (ca. 50%)	200
H ₂ C=CHCH ₂ Br	(C ₆ H ₅) ₃ CMgBr	H ₂ C=CHCH ₂ C(C ₆ H ₅) ₃ (88%)	10
C₃H₅I			
H ₂ C=CHCH ₂ I	<i>i</i> -C ₄ H ₉ MgCl	H ₂ C=CH- <i>i</i> -C ₅ H ₁₁ (50%); (H ₂ C=CHCH ₂ -) ₂ ; (<i>i</i> -C ₄ H ₉ -) ₂	5

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₅I (cont.)			
H ₂ C=CHCH ₂ I	C ₆ H ₅ CH ₂ MgCl	H ₂ C=CHCH ₂ CH ₂ C ₆ H ₅ (65%)	5
C₃H₆ClBrMgO			
BrMgO(CH ₂) ₃ Cl (49 g. C ₃ H ₇ ClO)	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ (CH ₂) ₄ OH (37 g., 50%)	266
BrMgO(CH ₂) ₃ Cl	C ₆ H ₅ CH ₂ CH ₂ MgBr	C ₆ H ₅ (CH ₂) ₅ OH (36%)	266
BrMgO(CH ₂) ₃ Cl	C ₆ H ₅ (CH ₂) ₃ MgBr	C ₆ H ₅ (CH ₂) ₆ OH (33%)	266
BrMgO(CH ₂) ₃ Cl	C ₆ H ₅ (CH ₂) ₄ MgBr	C ₆ H ₅ (CH ₂) ₇ OH (21%)	266
C₃H₆ClBrO			
BrCH ₂ CH(OH)CH ₂ Cl	C ₂ H ₅ MgBr*	(CH ₂) ₂ CHOH (6.3%)	253
C₃H₆Br₂			
Br(CH ₂) ₃ Br	C ₆ H ₄ -1,4-(MgBr) ₂	(C ₆ H ₄)-1,2-[(CH ₂) ₃ Br] ₂ ; (4-CH ₃ C ₆ H ₄ CH ₂) ₂ CH ₂	207
C₃H₇ClO			
C ₂ H ₅ OCH ₂ Cl	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ CH ₂ OC ₂ H ₅ (53x%); 2-CH ₃ C ₆ H ₄ CH ₂ OC ₂ H ₅ (16x%); 4-CH ₃ C ₆ H ₄ CH ₂ OC ₂ H ₅ (31x%)	72
C ₂ H ₅ OCH ₂ Cl (0.1 mole)	C ₆ H ₅ CH ₂ MgCl (0.1 mole C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CH ₂ OC ₂ H ₅ (92x%); 2-CH ₃ C ₆ H ₄ CH ₂ OC ₂ H ₅ (2x%); 4-CH ₃ C ₆ H ₄ CH ₂ OC ₂ H ₅ (6x%)	263
C ₂ H ₅ OCH ₂ Cl	(<i>n</i> -C ₃ H ₇) ₂ CHMgBr	C ₂ H ₅ OCH ₂ CH(<i>n</i> -C ₃ H ₇) ₂	2
CH ₃ (CH ₃ O)CHCl (0.1 mole)	C ₆ H ₅ CH ₂ MgCl (0.1 mole C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CH(CH ₃)OCH ₃ (99.0x%); 2-CH ₃ C ₆ H ₄ CH(CH ₃)OCH ₃ 0.8x%; 4-CH ₃ C ₆ H ₄ CH(CH ₃)OCH ₃ (0.2x%)	263

* From pure sublimed magnesium.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₇ClO₂			
HOCH ₂ CH(OH)CH ₂ Cl	C ₂ H ₅ MgBr	CH ₃ COCH ₂ OH	273,272
HOCH ₂ CH(OH)CH ₂ Cl	<i>i</i> -C ₅ H ₁₁ MgBr	HO(CH ₃)(<i>i</i> -C ₅ H ₁₁)CCH ₂ OH	86,87, 211, <i>cf.</i> 272
HOCH ₂ CH(OH)CH ₂ Cl	C ₆ H ₅ MgBr	HO(CH ₃)(C ₆ H ₅)CCH ₂ OH (chiefly); C ₆ H ₅ CH ₂ CH(OH)CH ₂ OH (a little)	86,87, 211, <i>cf.</i> 272
HOCH ₂ CH(OH)CH ₂ Cl	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ CH ₂ CH(OH)CH ₂ OH*	272
C₃H₇Br			
<i>n</i> -C ₃ H ₇ Br	C ₆ H ₅ MgBr + FeCl ₃ (trace)	<i>n</i> -C ₃ H ₇ C ₆ H ₅ (50-60%)	282,225
<i>n</i> -C ₃ H ₇ Br	C ₆ H ₅ CH ₂ MgBr + FeCl ₃ (trace)	<i>n</i> -C ₄ H ₉ C ₆ H ₅	225
<i>n</i> -C ₃ H ₇ Br	2-C ₁₀ H ₇ MgBr + FeCl ₃ (trace)	2- <i>n</i> -C ₃ H ₇ C ₁₀ H ₇	225
<i>n</i> -C ₃ H ₇ Br	9-Fluorenyl-MgBr	No reaction in boiling xylene	155
<i>n</i> -C ₃ H ₇ Br	9-Phenanthryl-MgBr	9- <i>n</i> -Propylphenanthrene (47%)	155
<i>n</i> -C ₃ H ₇ Br	(C ₆ H ₅) ₃ CMgBr	<i>n</i> -C ₃ H ₇ C(C ₆ H ₅) ₃ (41%)	10
<i>i</i> -C ₃ H ₇ Br	C ₆ H ₅ MgBr + FeCl ₃ (trace)	<i>i</i> -C ₃ H ₇ C ₆ H ₅ (50-60%)	282,225
<i>i</i> -C ₃ H ₇ Br	C ₆ H ₅ CH ₂ MgBr + FeCl ₃ (trace)	<i>i</i> -C ₄ H ₉ C ₆ H ₅	225
<i>i</i> -C ₃ H ₇ Br	1-C ₁₀ H ₇ MgBr + FeCl ₃ (trace)	1- <i>i</i> -C ₃ H ₇ C ₁₀ H ₇ (50-60%)	282
C₃H₇BrO			
CH ₃ CH(OH)CH ₂ Br	(C ₂ H ₅) ₂ Mg	CH ₃ CH(OH)- <i>n</i> -C ₃ H ₇	110
C₃H₇I			
<i>n</i> -C ₃ H ₇ I	CH ₃ MgI	C ₃ H ₆ ; saturated gases	212

*Probably an erroneous assignment of structure.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₃H₇I (<i>cont.</i>)			
<i>n</i> -C ₃ H ₇ I	C ₂ H ₅ MgI	Alkenes, comprising 45.8% C ₂ H ₄ , 54.2% C ₃ H ₆ ; alkanes, comprising 66% C ₂ H ₆ , 34% C ₃ H ₈	212
C₄H₄Cl₄O₂			
2,2,3,3-Tetrachloro-1,4-dioxane (0.1 mole)	<i>n</i> -C ₄ H ₉ MgBr (excess)	C ₄ H ₁₀ (0.13 mole); C ₄ H ₈ (0.12 mole); unidentified unsat'd Cl comp'ds	217
2,2,3,3-Tetrachloro-1,4-dioxane (9.1 g., 0.04 mole)	C ₆ H ₅ MgBr (0.25 mole)	2-Chloro-2,3,3-triphenyl-1,4-dioxane (10.5 g., 71%)	217
C₄H₄Br₂			
(≡CCH ₂ Br) (4.0 g.)	C ₂ H ₅ MgBr (1.4 g. Mg)	(≡C- <i>n</i> -C ₃ H ₇) ₂ (1.2 g., crude)	256
C₄H₅Cl			
H ₂ C=C=CHCH ₂ Cl	CH ₃ MgCl	H ₂ C=C(CH ₃)CH=CH ₂ (14.7%)	35,33
H ₂ C=C=CHCH ₂ Cl	CH ₃ MgI	H ₂ C=C(CH ₃)CH=CH ₂ (23.5%)	35,33
H ₂ C=C=CHCH ₂ Cl	<i>n</i> -C ₄ H ₉ MgBr	H ₂ C=C(<i>n</i> -C ₄ H ₉)CH=CH ₂ (13.1%)	35,33
H ₂ C=C=CHCH ₂ Cl	C ₆ H ₅ MgBr	H ₂ C=C=CHCH ₂ C ₆ H ₅ (4.0-7.2%); H ₂ C=C(C ₆ H ₅)CH=CH ₂ (8.4-9.2%); [H ₂ C=C(C ₆ H ₅)CH=CH ₂] ₂ (25.3-26.7%)	35,33
H ₂ C=C=CHCH ₂ Cl	C ₆ H ₅ CH ₂ MgCl	H ₂ C=C=CHCH ₂ CH ₂ C ₆ H ₅	33
H ₂ C=C=CHCH ₂ Cl	<i>n</i> -C ₇ H ₁₅ MgBr	H ₂ C=C(<i>n</i> -C ₇ H ₁₅)CH=CH ₂ (21.0%)	35,33
C₄H₅Cl₃			
Cl ₂ C=C(CH ₃)CH ₂ Cl	CH ₃ MgBr (5 equiv.)	Recovered trichloride; 1,1-dichloro-2,4,4,5-tetramethyl-1,5-hexadiene; 2,3,6,7-tetramethyl-2,6-octadiene; C ₂ H ₆	125

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₄H₆ClN			
NC(CH ₂) ₃ Cl*			
CH ₃ (NCCH ₂)CHCl*			
C₄H₆Cl₂			
ClCH=CHCH ₂ CH ₂ Cl (37 g.)	CH ₃ MgBr (75 g. CH ₃ Br)	(C ₂ H ₅ CH=) ₂ (24%); (H ₂ C=CH—) ₂ (50%)	146
ClCH=CHCH ₂ CH ₂ Cl	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ MgBr	ClCH=CH(CH ₂) ₂ C ₆ H ₄ -4- <i>i</i> -C ₃ H ₇ ("high yield")	17
H ₂ C=CHCHClCH ₂ Cl (41 g.)	CH ₃ MgBr (75 g. CH ₃ Br)	(C ₂ H ₅ CH=) ₂ (4.5 g.); (CH ₃ CHCl—) ₂ (18.0 g.)	146
H ₂ C=C(CH ₂ Cl) ₂	C ₆ H ₅ MgBr	H ₂ C=C(CH ₂ Cl)CH ₂ C ₆ H ₅	24
C₄H₆Cl₂O			
2,3-Dichlorotetrahydrofuran	RMgX [†] (2 equiv.)	2-R-3-Chlorotetrahydrofuran	161
C₄H₆Cl₂O₂			
2,3-Dichloro-1,4-dioxane	CH ₃ MgBr	Dihydro- <i>p</i> -dioxin (68%); 2,3-Dimethyl-1,4-dioxane (3%); gases: 94% C ₂ H ₆ ; 5.4% CH ₄ ; 0.6% C ₂ H ₄	215,214
2,3-Dichloro-1,4-dioxane	C ₂ H ₅ MgBr	Dihydro- <i>p</i> -dioxin (54%); 2,3-Diethyl-1,4-dioxane (2%)	215,214
2,3-Dichloro-1,4-dioxane	H ₂ C=CHCH ₂ MgBr	2,3-Diallyl-1,4-dioxane (18%); 1,3-hexadiene	215
2,3-Dichloro-1,4-dioxane	<i>n</i> -C ₄ H ₉ MgBr	2,3-Di- <i>n</i> -butyl-1,4-dioxane (2%)	215,214
2,3-Dichloro-1,4-dioxane	<i>n</i> -C ₄ H ₉ MgBr + ZnCl ₂	2,3-Di- <i>n</i> -butyl-1,4-dioxane (37%)	215
2,3-Dichloro-1,4-dioxane	<i>n</i> -C ₄ H ₉ MgBr + CdCl ₂	2,3-Di- <i>n</i> -butyl-1,4-dioxane (44%)	215

* See Table X-I, C₄H₆NCl.[†]R = CH₃, C₂H₅, *n*-C₃H₇, *n*-C₄H₉, C₆H₅.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₆Cl₂O₂ (cont.)			
2,3-Dichloro-1,4-dioxane	4-ClC ₆ H ₄ MgBr	2,3-Di- <i>p</i> -chlorophenyl-1,4-dioxane (49%)	215,36
2,3-Dichloro-1,4-dioxane	C ₆ H ₅ MgBr	2,3-Diphenyl-1,4-dioxane (80%)	215
2,3-Dichloro-1,4-dioxane	C ₆ H ₅ CH ₂ MgBr	2,3-Dibenzyl-1,4-dioxane (22%)	215
2,3-Dichloro-1,4-dioxane	2-CH ₃ C ₆ H ₄ MgBr	2,3-Di- <i>o</i> -tolyl-1,4-dioxane (61%)	215
2,3-Dichloro-1,4-dioxane	3-CH ₃ C ₆ H ₄ MgBr	2,3-Di- <i>m</i> -tolyl-1,4-dioxane (51%)	215
2,3-Dichloro-1,4-dioxane	4-CH ₃ C ₆ H ₄ MgBr	2,3-Di- <i>p</i> -tolyl-1,4-dioxane (72%)	215
2,3-Dichloro-1,4-dioxane	4-CH ₃ OC ₆ H ₄ MgBr	2,3-Di- <i>p</i> -anisyl-1,4-dioxane (67%)	215
2,3-Dichloro-1,4-dioxane	1-C ₁₀ H ₇ MgBr (4 equiv.)	2,3-Di- <i>α</i> -naphthyl-1,4-dioxane (53%)	215
C₄H₆BrN			
NC(CH ₂) ₃ Br*			
C₄H₆Br₂			
(=CHCH ₂ Br) ₂ (60 g.)	CH ₃ MgI (188 g. CH ₃ I)	(=CHC ₂ H ₅) ₂ (10-12%); C ₄ H ₆ Br ₄ , m. 117°	146
BrCH=C(CH ₃)CH ₂ Br	C ₂ H ₅ MgBr	C ₈ H ₁₆ (30%); C ₆ H ₁₁ Br; C ₁₀ H ₁₇ Br	291
C₄H₇Cl			
CH ₃ CH=CHCH ₂ Cl	H ₂ C=CHCH ₂ MgCl	(H ₂ C=CHCH ₂) ₂ CH ₂ (> 50.8%); H ₂ C=CHCH(CH ₃)CH ₂ CH=CH ₂ (< 3.2%)	245
CH ₃ CH=CH ₂ Cl (110 g.)	H ₂ C=CHCH ₂ MgBr (150 g. C ₃ H ₅ Br)	CH ₃ CH=CHCH ₂ CH ₂ CH=CH ₂ (62.6 g., 53.5%)	147
CH ₃ CH=CHCH ₂ Cl	Butenyl-MgBr	(CH ₃ CH=CHCH ₂ —) ₂ (8.6%); H ₂ C=CHCH(CH ₃)CH ₂ CH=CHCH ₃ (59.0%); [H ₂ C=CHCH(CH ₃)—] ₂ (5.0%)	245

* See Table X-I, C₄H₆NBr.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₄H₇Cl (cont.)			
CH ₃ CH=CHCH ₂ Cl	<i>n</i> -C ₄ H ₉ MgCl	CH ₃ CH=CH- <i>n</i> -C ₅ H ₁₁ (60%); H ₂ C=CHCH(CH ₃)- <i>n</i> -C ₄ H ₉ (10%)	38
CH ₃ CH=CHCH ₂ Cl	C ₆ H ₅ MgBr	CH ₃ CH=CHCH ₂ C ₆ H ₅ (46 ± 3%); H ₂ C=C(CH ₃)CH ₂ C ₆ H ₅ (14 ± 2%)	243
CH ₃ CH=CHCH ₂ Cl + CH ₃ (H ₂ C=CH)CHCl	<i>n</i> -C ₄ H ₉ MgCl	H ₂ C=CHCH(CH ₃)CH ₂ CH=CHCH ₃ (6x%); H ₂ C=CHCH(CH ₃)- <i>n</i> -C ₄ H ₉ (9x%); CH ₃ CH=CH- <i>n</i> -C ₅ H ₁₁ (85x%)	98
CH ₃ CH=CHCH ₂ Cl (41%) + CH ₃ (H ₂ C=CH)CHCl (59%)	C ₆ H ₅ MgBr	CH ₃ CH=CHCH ₂ C ₆ H ₅ (81 ± 3x%); CH ₃ (H ₂ C=CH)CHC ₆ H ₅ (19 ± 2x%)	243
CH ₃ (H ₂ C=CH)CHCl	H ₂ C=CHCH ₂ MgCl (<i>ca.</i> 1 equiv.)	(H ₂ C=CHCH ₂) ₂ CH ₂ (42.4%); H ₂ C=CHCH(CH ₃)CH ₂ CH=CH ₂ (13.2%)	245
CH ₃ (H ₂ C=CH)CHCl (0.38 mole)	Butenyl-MgBr (0.38 mole)	(CH ₃ CH=CHCH ₂ -) ₂ (2.3%); H ₂ C=CHCH(CH ₃)CH ₂ CH ₂ CH=CH ₂ (65.4%); [H ₂ C=CHCH(CH ₃)-] ₂ (8.4%)	245
CH ₃ (H ₂ C=CH)CHCl	C ₆ H ₅ MgBr	CH ₃ CH=CHCH ₂ C ₆ H ₅ (52 ± 4%); CH ₃ (H ₂ C=CH)CHC ₆ H ₅ (14 ± 2%)	243
H ₂ C=C(CH ₃)CH ₂ Cl	<i>n</i> -C ₄ H ₉ MgCl	H ₂ C=C(CH ₃)- <i>n</i> -C ₅ H ₁₁ ; (CH ₃) ₂ C=CH- <i>n</i> -C ₄ H ₉ *	98
H ₂ C=C(CH ₃)CH ₂ Cl	C ₆ H ₅ MgBr	H ₂ C=C(CH ₃)CH ₂ C ₆ H ₅	24
H ₂ C=C(CH ₃)CH ₂ Cl (36.5 kg.)	C ₆ H ₅ MgBr (404 moles C ₆ H ₅ Br)	H ₂ C=C(CH ₃)CH ₂ C ₆ H ₅ + (CH ₃) ₂ C=CHC ₆ H ₅ (totalling 45-53%)	30
C₄H₇ClO₂			
2-Chloro-1,4-dioxane	C ₆ H ₅ MgBr	2-Phenyl-1,4-dioxane (49%)	214

* This product is attributed to rearrangement of the primary product; the extent of rearrangement is said to depend upon the temperature of reaction and of the recovery operations.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₄H₇Br			
CH ₃ CH=CHCH ₂ Br (60 g.)	C ₆ H ₅ MgBr (79 g. C ₆ H ₅ Br)	CH ₃ CH=CHCH ₂ C ₆ H ₅ (34%)	285
CH ₃ CH=CHCH ₂ Br	C ₆ H ₅ CH ₂ CH ₂ MgBr	H ₂ C=CHCH(CH ₃)CH ₂ CH ₂ C ₆ H ₅	285
Butenyl bromide* (10-15% excess)	Butenyl-MgBr (0.6 mole)	(CH ₃ CH=CHCH ₂ —) ₂ (5.8%); H ₂ C=CHCH(CH ₃)CH ₂ CH=CHCH ₃ (51.0%); [H ₂ C=CHCH(CH ₃)—] ₂ (1.2%)	245
CH ₃ (H ₂ C=CH)CHBr (10-15% excess)	Butenyl-MgBr (0.6 mole)	(CH ₃ CH=CHCH ₂ —) ₂ (37.5%); H ₂ C=CHCH(CH ₃)CH ₂ CH=CHCH ₃ (26.3%); [H ₂ C=CHCH(CH ₃)—] ₂ (11.3%)	245
CH ₃ (H ₂ C=CH)CHBr + CH ₃ CH=CHCH ₂ Br [†] (107 g.)	(CH ₂) ₄ CHMgCl (82 g. C ₅ H ₉ Cl)	CH ₃ (H ₂ C=CH)CHCH(CH ₂) ₄ (8.3 g.); <i>cis</i> - and <i>trans</i> -CH ₃ CH=CHCH ₂ CH(CH ₂) ₄ (5.4 g.)	170
CH ₃ (H ₂ C=CH)CHBr	C ₆ H ₅ CH ₂ CH ₂ MgBr	CH ₃ CH=CH(CH ₂) ₃ C ₆ H ₅	285
C₄H₇Br₂ClO			
ClCH ₂ CH ₂ OCHBrCH ₂ Br	C ₂ H ₅ MgBr (<i>ca.</i> 1 equiv.)	ClCH ₂ CH ₂ OCH(CH ₂ Br)C ₂ H ₅ (81%)	40,216
ClCH ₂ CHBr(CH ₃ O)CHBr	<i>n</i> -C ₃ H ₇ MgBr	ClCH ₂ CHBrCH(OCH ₃)- <i>n</i> -C ₃ H ₇	181
ClCH ₂ CHBr(CH ₃ O)CHBr	<i>n</i> -C ₄ H ₉ Br	ClCH ₂ CHBrCH(OCH ₂)- <i>n</i> -C ₄ H ₉	181
C₄H₈Cl₂O			
ClCH ₂ (C ₂ H ₅ O)CHCl	(≡CMgX) ₂ [‡]	[ClCH ₂ (C ₂ H ₅ O)CHC≡] ₂	141
ClCH ₂ (C ₂ H ₅ O)CHCl (100 g.)	C ₂ H ₅ MgBr (120 g. C ₂ H ₅ Br)	ClCH ₂ (C ₂ H ₅ O)CHC ₂ H ₅ (<i>ca.</i> 70 g.)	107
ClCH ₂ (C ₂ H ₅ O)CHCl (70 g.)	<i>i</i> -C ₄ H ₉ MgBr (70 g. C ₄ H ₉ Br)	ClCH ₂ (C ₂ H ₅ O)CH- <i>i</i> -C ₄ H ₉ (50 g., crude)	107

* Comprising 87 percent crotyl bromide, CH₃CH=CHCH₂Br, and 13 percent α-methallyl bromide, CH₃(H₂C=CH)CHBr.

[†] From the addition of hydrogen bromide to 1,3-butadiene.

[‡] Lespieau and Bresch (141) describe the Grignard reagent employed as HC≡CMgX, but in view of the reported product and of the known difficulty of preparing the monomagnesium reagent this appears improbable.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₄H₈Cl₂O (cont.)			
ClCH ₂ (C ₂ H ₅ O)CHCl (80 g.)	<i>i</i> -C ₅ H ₁₁ MgBr (100 g. C ₅ H ₁₁ Br)	ClCH ₂ (C ₂ H ₅ O)CH- <i>i</i> -C ₅ H ₁₁ (75 g.)	107
ClCH ₂ (C ₂ H ₅ O)CHCl (115 g.)	C ₆ H ₅ MgBr (150 g. C ₆ H ₅ Br)	ClCH ₂ (C ₂ H ₅ O)CHC ₆ H ₅ (97 g.)	107
ClCH ₂ (C ₂ H ₅ O)CHCl (75 g.)	C ₆ H ₅ CH ₂ MgCl (100 g. C ₇ H ₇ Cl)	ClCH ₂ (C ₂ H ₅ O)CHCH ₂ C ₆ H ₅ (54 g.)	107
ClCH ₂ (C ₂ H ₅ O)CHCl	C ₆ H ₅ C ≡ CMgBr	ClCH ₂ (C ₂ H ₅ O)CHC ≡ CC ₆ H ₅	113
ClCH ₂ (C ₂ H ₅ O)CHCl (90 g.)	1-C ₁₀ H ₇ MgBr (150 g. C ₁₀ H ₇ Br)	ClCH ₂ (C ₂ H ₅ O)CH-1-C ₁₀ H ₇ (74 g.)	107
C₄H₈Br₂O			
BrCH ₂ (C ₂ H ₅ O)CHBr	CH ₃ MgBr (slight excess)	BrCH ₂ (C ₂ H ₅ O)CHCH ₃ (77.4%)*	218
BrCH ₂ (C ₂ H ₅ O)CHBr	CH ₃ MgBr (10-30% excess)	BrCH ₂ (C ₂ H ₅ O)CHCH ₃ (71%) [†]	202
BrCH ₂ (C ₂ H ₅ O)CHBr	(≡ CMgX) ₂	BrCH ₂ (C ₂ H ₅ O)CHC ≡ CH; [BrCH ₂ (C ₂ H ₅ O)CHC ≡] ₂	144
BrCH ₂ (C ₂ H ₅ O)CHBr	C ₂ H ₅ MgBr (slight excess)	BrCH ₂ (C ₂ H ₅ O)CHC ₂ H ₅ (60-75%)	218, 51, 202
BrCH ₂ (C ₂ H ₅ O)CHBr	H ₂ C = CHCH ₂ MgBr (slight excess)	BrCH ₂ (C ₂ H ₅ O)CHCH ₂ CH = CH ₂ (48-50%)	205
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>n</i> -C ₃ H ₇ MgBr (slight excess)	BrCH ₂ (C ₂ H ₅ O)CH- <i>n</i> -C ₃ H ₇ (66.5%)	218, 51
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>i</i> -C ₃ H ₇ MgBr (slight excess)	BrCH ₂ (C ₂ H ₅ O)CH- <i>i</i> -C ₃ H ₇ (30.0%)	218
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>n</i> -C ₄ H ₉ MgBr (slight excess)	BrCH ₂ (C ₂ H ₅ O)CH- <i>n</i> -C ₄ H ₉ (70.0%)	218, 51, 202, 231
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>i</i> -C ₄ H ₉ MgBr (slight excess)	BrCH ₂ (C ₂ H ₅ O)CH- <i>i</i> -C ₄ H ₉ (46-48%)	51, 202
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>s</i> -C ₄ H ₉ MgBr (10-30% excess)	BrCH ₂ (C ₂ H ₅ O)CH- <i>s</i> -C ₄ H ₉ (30%)	202
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>n</i> -C ₃ H ₇ C ≡ CMgBr	BrCH ₂ (C ₂ H ₅ O)CHC ≡ C- <i>n</i> -C ₃ H ₇ (80%)	6
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>n</i> -C ₅ H ₁₁ MgBr	BrCH ₂ (C ₂ H ₅ O)CH- <i>n</i> -C ₅ H ₁₁ (61-66%)	210
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>i</i> -C ₅ H ₁₁ MgBr	BrCH ₂ (C ₂ H ₅ O)CH- <i>i</i> -C ₅ H ₁₁ (55-60%)	210, 218, 51
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>s</i> -C ₄ H ₉ CH ₂ MgBr	BrCH ₂ (C ₂ H ₅ O)CHCH ₂ - <i>s</i> -C ₄ H ₉ (60%)	210

* Dropwise addition of Grignard reagent solution to ice-cooled, agitated Et₂O-bromide solution.

[†] Slow addition of Et₂O-bromide solution to ice-cooled, stirred Grignard reagent solution; ten to fifteen hours stirring.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₄H₉Br₂O (cont.)			
BrCH ₂ (C ₂ H ₅ O)CHBr	CH ₃ (<i>n</i> -C ₃ H ₇)CHMgBr	BrCH ₂ (C ₂ H ₅ O)CHCH(CH ₃)- <i>n</i> -C ₃ H ₇ (22-36%)	210
BrCH ₂ (C ₂ H ₅ O)CHBr	C ₆ H ₅ MgBr	BrCH ₂ (C ₂ H ₅ O)CHC ₆ H ₅ (90%)	234
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>n</i> -C ₄ H ₉ C ≡ CMgBr	BrCH ₂ (C ₂ H ₅ O)CHC ≡ C- <i>n</i> -C ₄ H ₉ (86%)	6
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>n</i> -C ₅ H ₁₁ C ≡ CMgBr	BrCH ₂ (C ₂ H ₅ O)CHC ≡ C- <i>n</i> -C ₅ H ₁₁ (84%)	6
BrCH ₂ (C ₂ H ₅ O)CHBr	C ₆ H ₅ C ≡ CMgBr	BrCH ₂ (C ₂ H ₅ O)CHC ≡ CC ₆ H ₅ (60%)	180, 78, 179
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>n</i> -C ₆ H ₁₃ C ≡ CMgBr	BrCH ₂ (C ₂ H ₅ O)CHC ≡ C- <i>n</i> -C ₆ H ₁₃ (85%)	6
BrCH ₂ (C ₂ H ₅ O)CHBr	<i>n</i> -C ₈ H ₁₇ C ≡ CMgBr	BrCH ₂ (C ₂ H ₅ O)CHC ≡ C- <i>n</i> -C ₈ H ₁₇ (81%)	6
BrCH ₂ (C ₂ H ₅ O)CHBr (0.72 mole)	4-C ₆ H ₅ CH ₂ CH ₂ C ₆ H ₄ MgBr (0.71 mole)	BrCH ₂ (C ₂ H ₅ O)CHC ₆ H ₄ -4-CH ₂ CH ₂ C ₆ H ₅ (53%)*	254
BrCH ₂ (C ₂ H ₅ O)CHBr (0.1 mole)	4-C ₆ H ₅ CH ₂ CH ₂ C ₆ H ₄ MgBr (0.1 mole C ₁₄ H ₁₃ Br)	BrCH ₂ (C ₂ H ₅ O)CHC ₆ H ₄ -4-CH ₂ CH ₂ C ₆ H ₅ (31%)†	254
C₄H₉Cl			
<i>t</i> -C ₄ H ₉ Cl	CH ₃ MgCl	C(CH ₃) ₄ (42-50%)	236
<i>t</i> -C ₄ H ₉ Cl (400 g.)	C ₂ H ₅ MgBr (654 g. C ₂ H ₅ Br) + CuI (20 g.)	<i>t</i> -C ₄ H ₉ C ₂ H ₅ (11%)	150
<i>t</i> -C ₄ H ₉ Cl	<i>n</i> -C ₃ H ₇ MgBr + CuI	<i>t</i> -C ₄ H ₉ - <i>n</i> -C ₃ H ₇ (21%)	150
<i>t</i> -C ₄ H ₉ Cl (4 moles)	<i>n</i> -C ₃ H ₇ MgBr (4 moles C ₃ H ₇ Br) + HgCl ₂ (30 g.)	<i>t</i> -C ₄ H ₉ - <i>n</i> -C ₃ H ₇ (21%); C ₈ H ₁₈ ; C ₆ H ₁₄ ; olefins	52; c/ 241
<i>t</i> -C ₄ H ₉ Cl	<i>n</i> -C ₄ H ₉ MgBr + CuI	<i>t</i> -C ₄ H ₉ - <i>n</i> -C ₄ H ₉ (14%)	150
<i>t</i> -C ₄ H ₉ Cl (5.5 moles) + <i>t</i> -C ₄ H ₉ I (0.5 mole)	<i>t</i> -C ₄ H ₉ MgCl (6.0 moles) + CuCl (20 g.)	(<i>t</i> -C ₄ H ₉ —) ₂ (122 g.)	150
<i>t</i> -C ₄ H ₉ Cl	<i>t</i> -C ₄ H ₉ MgBr	(<i>t</i> -C ₄ H ₉ —) ₂ (4%)	240
<i>t</i> -C ₄ H ₉ Cl	<i>n</i> -C ₅ H ₁₁ MgBr + CuI	<i>t</i> -C ₄ H ₉ - <i>n</i> -C ₅ H ₁₁ (17%)	150

* Slow addition of Grignard reagent solution to bromide; forty-eight hours stirring.

† Slow addition of bromide to Grignard reagent solution; twenty-two hours stirring.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₄H₉Cl (cont.)			
<i>t</i> -C ₄ H ₉ Cl (40 g.)	2,4-(CH ₃) ₂ C ₆ H ₃ MgI (53 g. C ₈ H ₉ I)	<i>t</i> -C ₄ H ₉ C ₅ H ₃ -2,4-(CH ₃) ₂ (2.5 g.)	209
C₄H₉ClO			
<i>n</i> -C ₃ H ₇ OCH ₂ Cl (0.1 mole)	C ₆ H ₅ CH ₂ MgCl (0.1 mole C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CH ₂ O- <i>n</i> -C ₃ H ₇ (95.0%); 2-CH ₃ C ₆ H ₄ CH ₂ O- <i>n</i> -C ₃ H ₇ (2.5%); 4-CH ₃ C ₆ H ₄ CH ₂ O- <i>n</i> -C ₃ H ₇ (2.5%)	263
CH ₃ (C ₂ H ₅ O)CHCl	C ₆ H ₅ C≡CMgBr	CH ₃ (C ₂ H ₅ O)CHC≡CC ₆ H ₅ (50%)	180
C₄H₉ClO₂			
CH ₃ OCH ₂ CH(OH)CH ₂ Cl	C ₆ H ₅ MgBr	CH ₃ OCH ₂ CH(OH)CH ₂ C ₆ H ₅	187
C₄H₉Br			
<i>n</i> -C ₄ H ₉ Br	HC≡CMgBr	<i>n</i> -C ₄ H ₉ C≡CH (72%)	90,196, 219
<i>n</i> -C ₄ H ₉ Br	C ₆ H ₅ MgBr + FeCl ₃ (trace)	<i>n</i> -C ₄ H ₉ C ₆ H ₅ (50-60%)	282,225
<i>n</i> -C ₄ H ₉ Br	C ₆ H ₅ CH ₂ MgBr + FeCl ₃ (trace)	<i>n</i> -C ₅ H ₁₁ C ₆ H ₅	225
<i>n</i> -C ₄ H ₉ Br	1-C ₁₀ H ₇ MgBr + FeCl ₃ (trace)	1- <i>n</i> -C ₄ H ₉ C ₁₀ H ₇ (50-60%)	282
<i>n</i> -C ₄ H ₉ Br	9-Fluorenyl-MgBr	No reaction*	155
<i>n</i> -C ₄ H ₉ Br	9-Phenanthryl-MgBr	9- <i>n</i> -Butylphenanthrene (52%)	155
<i>i</i> -C ₄ H ₉ Br	C ₆ H ₅ MgBr	<i>i</i> -C ₄ H ₉ C ₆ H ₅ (20%); (C ₆ H ₅ —) ₂	212
<i>i</i> -C ₄ H ₉ Br	C ₆ H ₅ MgBr + FeCl ₃ (trace)	<i>i</i> -C ₄ H ₉ C ₆ H ₅	282,225
(-)- <i>s</i> -C ₄ H ₉ Br, [α] _D ²⁵ - 16.80 (21.2 g., 0.155 mole)	C ₆ H ₅ CH ₂ MgCl (76.0 g., 0.600 mole C ₇ H ₇ Cl)	<i>s</i> -C ₄ H ₉ CH ₂ C ₆ H ₅ , [α] _D ²⁵ + 0.64 (3.8 g., 17%)	286
<i>s</i> -C ₄ H ₉ Br (46 g.)	C ₆ H ₅ CH ₂ MgCl (50 g. C ₇ H ₇ Cl)	<i>s</i> -C ₄ H ₉ CH ₂ C ₆ H ₅ (5 g., 10%)	261
<i>t</i> -C ₄ H ₉ Br	CH ₃ MgI	(CH ₃) ₂ C=CH ₂ (38.7%); CH ₄ ; C(CH ₃) ₄ ; (<i>t</i> -C ₄ H ₉ —) ₂	212

* Five hours reflux in xylene.

TABLE XVI-I (Continued)

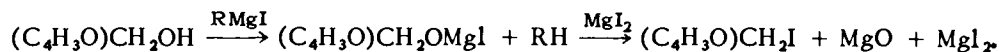
Halide	RMgX	Product(s)	Ref.
C₄H₉Br (cont.)			
<i>t</i> -C ₄ H ₉ Br	CH ₃ MgI	C(CH ₃) ₄ (18.2%)	236
<i>t</i> -C ₄ H ₉ Br	C ₆ H ₅ MgBr	<i>t</i> -C ₄ H ₉ C ₆ H ₅ (33%); (CH ₃) ₂ C=CH ₂ ; (C ₆ H ₅ —) ₂	212
<i>t</i> -C ₄ H ₉ Br	C ₆ H ₅ CH ₂ MgCl	<i>t</i> -C ₄ H ₉ CH ₂ C ₆ H ₅ (ca. 30%); (C ₆ H ₅ CH ₂ —) ₂	31
<i>t</i> -C ₄ H ₉ Br	?-CH ₃ -5-CH ₃ OC ₆ H ₃ MgBr	<i>t</i> -C ₄ H ₉ C ₆ H ₃ -3-CH ₃ -5-OCH ₃	48
<i>t</i> -C ₄ H ₉ Br	1-C ₁₀ H ₇ MgBr	1- <i>t</i> -C ₄ H ₉ C ₁₀ H ₇ ('a little'); (1,1'-C ₁₀ H ₇ —) ₂ ; C ₁₀ H ₈	212
<i>t</i> -C ₄ H ₉ Br	(C ₆ H ₅) ₃ CMgBr	(C ₆ H ₅) ₃ CH (73%)	10
C₄H₉BrO			
CH ₃ CH(OH)CH(CH ₃)Br	CH ₃ MgI (2 equiv.)	'Hexene'* b. 69–70° (13%)	79
CH ₃ CH(OH)CH(CH ₃)Br (0.65 mole)	C ₂ H ₅ MgBr (1.30 mole)	CH ₃ COC ₂ H ₅ (1.0 g.); <i>n</i> -C ₃ H ₇ (CH ₃) ₂ COH (17.4 g., 26%); CH ₃ (C ₂ H ₅) ₂ COH (0.6 g.)	41
C₄H₉I			
<i>t</i> -C ₄ H ₉ I	CH ₃ MgI	C(CH ₃) ₄ (15–20%)	55
<i>t</i> -C ₄ H ₉ I	C ₆ H ₅ CH ₂ MgCl	<i>t</i> -C ₄ H ₉ CH ₂ C ₆ H ₅ (30%); (C ₆ H ₅ CH ₂ —) ₂	31
<i>t</i> -C ₄ H ₉ I	3-CH ₃ -5-CH ₃ OC ₆ H ₃ MgBr	<i>t</i> -C ₄ H ₉ C ₆ H ₃ -3-CH ₃ -5-OCH ₃	48
C₄H₁₀ClN			
(CH ₃) ₂ NCH ₂ CH ₂ Cl (330 g., 2.44 moles)	H ₂ C=CHCH ₂ MgCl (230 g. C ₃ H ₅ Cl)	(CH ₃) ₂ N(CH ₂) ₃ CH=CH ₂ (85%)	119

* In a personal communication from D. L. Cottle to Gaylord and Becker, *Chem. Revs.*, 49, 471 (1950), it is stated that this product has been identified as 3-methyl-2-pentene.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₅H₅IO			
2-Iodomethylfuran* (from 6 g. C ₄ H ₆ O ₂)	<i>n</i> -C ₃ H ₇ MgI (65 g. C ₃ H ₇ I)	2- <i>n</i> -Butylfuran	132
2-Iodomethylfuran* (from 6 g. C ₄ H ₆ O ₂)	<i>i</i> -C ₄ H ₉ MgI (70 g. C ₄ H ₉ I)	2-Isoamylfuran	132
2-Iodomethylfuran*	<i>i</i> -C ₅ H ₁₁ MgI	2-Isohexylfuran	132
C₅H₇Cl			
3-Chlorocyclopentene (8.7 moles)	CH ₃ MgCl (12 moles)	3-Methylcyclopentene (23.7%) [†]	42
3-Chlorocyclopentene (8.5 moles)	C ₂ H ₅ MgCl (12 moles)	3-Ethylcyclopentene (48.3%) [†]	42
3-Chlorocyclopentene (3.0 moles)	C ₂ H ₅ MgBr (3.7 moles)	3-Ethylcyclopentene (42.7%) [†]	42,228
3-Chlorocyclopentene (14.1 moles)	<i>n</i> -C ₃ H ₇ MgCl (20 moles)	3- <i>n</i> -Propylcyclopentene (47.5%) [†]	42
3-Chlorocyclopentene (7.34 moles)	<i>n</i> -C ₃ H ₇ MgBr (8 moles)	3- <i>n</i> -Propylcyclopentene (37.9%) [†]	42
3-Chlorocyclopentene (8.95 moles)	<i>n</i> -C ₃ H ₇ MgBr (11 moles)	3- <i>n</i> -Propylcyclopentene (15.6%) [§]	42
3-Chlorocyclopentene (9.32 moles)	<i>n</i> -C ₃ H ₇ MgBr (12 moles)	3- <i>n</i> -Propylcyclopentene (41.1%) [†]	42
3-Chlorocyclopentene (14.6 moles)	<i>n</i> -C ₃ H ₇ MgBr (18 moles)	3- <i>n</i> -Propylcyclopentene (17.8%) [¶]	42
3-Chlorocyclopentene (9.2 moles)	<i>i</i> -C ₃ H ₇ MgCl (12 moles)	3-Isopropylcyclopentene (27.6%) [†]	42
3-Chlorocyclopentene (3.7 moles)	<i>i</i> -C ₃ H ₇ MgBr (3.7 moles)	3-Isopropylcyclopentene (20.0%) [†]	42
3-Chlorocyclopentene (3.1 moles)	<i>n</i> -C ₄ H ₉ MgBr (5 moles)	3- <i>n</i> -Butylcyclopentene (46.3%) [†]	42
3-Chlorocyclopentene (3.1 moles)	<i>i</i> -C ₄ H ₉ MgBr (5 moles)	3-Isobutylcyclopentene (39.0%) [†]	42
3-Chlorocyclopentene (13.7 moles)	<i>s</i> -C ₄ H ₉ MgBr (18 moles)	3- <i>s</i> -Butylcyclopentene (23.7%) [†]	42

* The alcohol was added to an excess of RMgI with which it presumably reacted as follows:



[†] Normal order of addition; copper reaction vessel.

[‡] Normal order of addition; glass reaction vessel.

[§] Reverse order of addition; copper reaction vessel.

[¶] Normal order of addition; steel reaction vessel.

TABLE XVI-1 (Continued)

Halide	RMgX	Product(s)	Ref.
C₅H₇Cl (cont.)			
3-Chlorocyclopentene (14.2 moles)	<i>t</i> -C ₄ H ₉ MgBr (18 moles)	3- <i>t</i> -Butylcyclopentene (2.0%)*	42
3-Chlorocyclopentene	(CH ₂) ₄ CHMgBr	3-Cyclopentylcyclopentene (<i>ca.</i> 60%)	228
3-Chlorocyclopentene	<i>n</i> -C ₅ H ₁₁ MgBr	3- <i>n</i> -Amylcyclohexene (43%)	171
3-Chlorocyclopentene	<i>i</i> -C ₅ H ₁₁ MgBr	3-Isoamylcyclopentene (60%)	228
3-Chlorocyclopentene	C ₆ H ₅ MgBr	3-Cyclopentenylbenzene (75%)	229
3-Chlorocyclopentene	(CH ₂) ₅ CHMgBr	3-Cyclopentenylcyclohexane (<i>ca.</i> 60%)	228
3-Chlorocyclopentene	<i>n</i> -C ₆ H ₁₃ MgBr	3- <i>n</i> -Hexylcyclopentene (38%)	171
3-Chlorocyclopentene	3-Ethylcyclopentyl-MgBr	1-Ethyl-3-(3-cyclopentenyl)cyclopentane (34%)	230
3-Chlorocyclopentene	<i>n</i> -C ₇ H ₁₅ MgBr	3- <i>n</i> -Heptylcyclopentene (50%)	230
3-Chlorocyclopentene	3-Bicyclopentyl-MgBr	"Quatercyclopentyl" (12%); 3-(3-Cyclopentenyl)bicyclopentyl (20%)	230
3-Chlorocyclopentene	<i>n</i> -C ₁₂ H ₂₅ MgCl	3- <i>n</i> -Dodecylcyclopentene (<i>ca.</i> 50%)	228
C₅H₇I			
<i>n</i> -C ₃ H ₇ C≡CI	<i>n</i> -C ₃ H ₇ C≡CMgI	(<i>n</i> -C ₃ H ₇ C≡C—) ₂ (<i>ca.</i> 60%)	91
C₅H₈Cl₂O			
2,3-Dichlorotetrahydropyran	<i>n</i> -C ₄ H ₉ MgCl	2- <i>n</i> -Butyl-3-chlorotetrahydropyran (70%)	169,168
2,3-Dichlorotetrahydropyran	C ₆ H ₅ MgBr	2-Phenyl-3-chlorotetrahydropyran (70%)	168
C₅H₈Br₂O			
2,3-Dibromotetrahydropyran	C ₂ H ₅ MgX	2-Ethyl-3-bromotetrahydropyran (<75%) [†]	167
2,3-Dibromotetrahydropyran	C ₆ H ₅ MgX	2-Phenyl-3-bromotetrahydropyran (<75%) [†]	167

* Normal order of addition; copper reaction vessel.

[†] Yields are reported to be somewhat less for the dibromo compound than in corresponding reactions of the monobromo derivative (*i.e.*, *ca.* 75–85%).

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₅H₉Cl			
CH ₃ (CH ₃ CH=CH)CHCl	<i>n</i> -C ₃ H ₇ MgCl	CH ₃ (CH ₃ CH=CH)CH- <i>n</i> -C ₃ H ₇	98
C₅H₉Br			
C ₂ H ₅ CH=CHCH ₂ Br	C ₂ H ₅ MgBr (slight excess)	C ₂ H ₅ CH=CH- <i>n</i> -C ₃ H ₇ (1 part); (C ₂ H ₅) ₂ CHCH=CH ₂ (3-4 parts)*	174,172
C ₂ H ₅ CH=CHCH ₂ Br	C ₆ H ₅ MgBr (slight excess)	C ₂ H ₅ CH=CHCH ₂ C ₆ H ₅ (1 part); C ₂ H ₅ (C ₆ H ₅)CHCH=CH ₂ (2-3 parts) [†]	174
CH ₃ (CH ₃ CH=CH)CHBr	CH ₃ MgBr	CH ₃ CH=CH(CH ₃) ₂ CH (57%)	160
CH ₃ (CH ₃ CH=CH)CHBr	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (CH ₃ CH=CH)CH- <i>n</i> -C ₃ H ₇ (27%)	160
CH ₃ (CH ₃ CH=CH)CHBr	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ (CH ₃ CH=CH)CH- <i>n</i> -C ₄ H ₉ (28%)	160
CH ₃ (CH ₃ CH=CH)CHBr	<i>i</i> -C ₄ H ₉ MgBr	CH ₃ (CH ₃ CH=CH)CH- <i>i</i> -C ₄ H ₉ (36%)	160
CH ₃ (CH ₃ CH=CH)CHBr	<i>s</i> -C ₄ H ₉ MgBr	CH ₃ (CH ₃ CH=CH)CH- <i>s</i> -C ₄ H ₉ (8%)	160
CH ₃ (CH ₃ CH=CH)CHBr	<i>t</i> -C ₄ H ₉ MgCl	CH ₃ (CH ₃ CH=CH)CH- <i>t</i> -C ₄ H ₉ (5%)	160
CH ₃ (CH ₃ CH=CH)CHBr	(CH ₂) ₄ CHMgBr	CH ₃ (CH ₃ CH=CH)CHCH(CH ₂) ₄ (15%)	160
C₅H₉BrO			
2-Bromotetrahydropyran	C ₂ H ₅ MgX	2-Ethyltetrahydropyran (75-85%)	167
2-Bromotetrahydropyran	<i>n</i> -C ₃ H ₇ MgX	2- <i>n</i> Propyltetrahydropyran (75-85%)	167
2-Bromotetrahydropyran	C ₆ H ₅ MgX	2-Phenyltetrahydropyran (75-85%)	167
C₅H₁₀Br₂O			
BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CHBr	CH ₃ MgBr (slight excess)	BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CHCH ₃ (61%)	51
BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CHBr	C ₂ H ₅ MgBr (slight excess)	BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CHC ₂ H ₅ (73%)	51
BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CHBr	<i>n</i> -C ₃ H ₇ MgBr (slight excess)	BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CH- <i>n</i> -C ₃ H ₇ (70%)	51
BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CHBr	<i>i</i> -C ₃ H ₇ MgBr (slight excess)	BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CH- <i>i</i> -C ₃ H ₇ (34%)	51

* Total yield, based on bromide, *ca.* 80%.[†] The total yield is reported as "excellent".

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₅H₁₀Br₂O (cont.)			
BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CHBr	<i>n</i> -C ₄ H ₉ MgBr (slight excess)	BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CH- <i>n</i> -C ₄ H ₉ (81%)	51
BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CHBr	<i>i</i> -C ₅ H ₁₁ MgBr (slight excess)	BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CH- <i>i</i> -C ₅ H ₁₁ (58%)	51
BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CHBr	C ₆ H ₅ MgBr (slight excess)	BrCH ₂ (<i>n</i> -C ₃ H ₇ O)CHC ₆ H ₅ (72%)	51
BrCH ₂ (CH ₃)(C ₂ H ₅ O)CBr	<i>n</i> -C ₄ H ₉ MgBr	BrCH ₂ (CH ₃)(C ₂ H ₅ O)C- <i>n</i> -C ₄ H ₉ (35%)	210
BrCH ₂ (CH ₃)(C ₂ H ₅ O)CBr	<i>i</i> -C ₄ H ₉ MgBr	BrCH ₂ (CH ₃)(C ₂ H ₅ O)C- <i>i</i> -C ₄ H ₉ (42%)	210
BrCH ₂ (CH ₃)(C ₂ H ₅ O)CBr	<i>s</i> -C ₄ H ₉ MgBr	BrCH ₂ (CH ₃)(C ₂ H ₅ O)- <i>s</i> -C ₄ H ₉ (21-25%)	210
CH ₃ CHBr(C ₂ H ₅ O)CHBr	H ₂ C=CHCH ₂ MgBr (slight excess)	CH ₃ CHBr(C ₂ H ₅ O)CHCH ₂ CH=CH ₂ (38-43%)	205
CH ₃ CHBr(C ₂ H ₅ O)CHBr	<i>n</i> -C ₃ H ₇ MgBr (10-30% excess)	CH ₃ CHBr(C ₂ H ₅ O)CH- <i>n</i> -C ₃ H ₇ (60%)	202
CH ₃ CHBr(C ₂ H ₅ O)CHBr	<i>i</i> -C ₃ H ₇ MgBr (10-30% excess)	CH ₃ CHBr(C ₂ H ₅ O)CH- <i>i</i> -C ₃ H ₇ (55%)	202
CH ₃ CHBr(C ₂ H ₅ O)CHBr	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ CHBr(C ₂ H ₅ O)CH- <i>n</i> -C ₄ H ₉ (69%)	210
CH ₃ CHBr(C ₂ H ₅ O)CHBr	<i>i</i> -C ₄ H ₉ MgBr	CH ₃ CHBr(C ₂ H ₅ O)CH- <i>i</i> -C ₄ H ₉ (49%)	210
CH ₃ CHBr(C ₂ H ₅ O)CHBr	<i>s</i> -C ₄ H ₉ MgBr	CH ₃ CHBr(C ₂ H ₅ O)CH- <i>s</i> -C ₄ H ₉ (31%)	210
C ₂ H ₅ CHBr(CH ₃ O)CHBr	C ₂ H ₅ MgBr (10-30% excess)	C ₂ H ₅ CHBr(CH ₃ O)CHC ₂ H ₅ (68%)	202
C₅H₁₁Cl			
<i>t</i> -C ₅ H ₁₁ Cl (6 moles)	C ₂ H ₅ MgBr (9 moles) + HgCl ₂ (30 g.)	<i>t</i> -C ₅ H ₁₁ C ₂ H ₅ (13-27%); C ₁₀ H ₂₂ ; C ₄ H ₁₀ ; olefins	52; cf. 241
<i>t</i> -C ₅ H ₁₁ Cl	C ₂ H ₅ MgBr + CuI	<i>t</i> -C ₅ H ₁₁ C ₂ H ₅ (22%)	150
<i>t</i> -C ₅ H ₁₁ Cl	<i>n</i> -C ₃ H ₇ Br	<i>t</i> -C ₅ H ₁₁ - <i>n</i> -C ₃ H ₇ (15%); C ₁₀ H ₂₂ ; unidentified gases	212
<i>t</i> -C ₅ H ₁₁ Cl	<i>n</i> -C ₃ H ₇ MgBr + CuI	<i>t</i> -C ₅ H ₁₁ - <i>n</i> -C ₃ H ₇ (17%)	150
<i>t</i> -C ₅ H ₁₁ Cl	<i>n</i> -C ₄ H ₉ MgBr + CuI	<i>t</i> -C ₅ H ₁₁ - <i>n</i> -C ₄ H ₉ (16%)	150
<i>t</i> -C ₅ H ₁₁ Cl	<i>n</i> -C ₅ H ₁₁ MgBr + CuI	<i>t</i> -C ₅ H ₁₁ - <i>n</i> -C ₅ H ₁₁ (11%)	150
C₅H₁₁ClO			
<i>n</i> -C ₄ H ₉ OCH ₂ Cl (0.29 mole)	Butenyl-MgBr (0.29 mole)	<i>n</i> -C ₄ H ₉ OCH ₂ CH(CH ₃)CH=CH ₂ (29.3 g., 70%); octadienes	245

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₅H₁₁ClO (<i>cont.</i>)			
<i>n</i> -C ₃ H ₇ CH(OH)CH ₂ Cl (0.32 mole)	C ₂ H ₅ MgBr (0.636 mole)	Recovered chlorohydrin; (<i>n</i> -C ₃ H ₇) ₂ CHOH	148
CH ₃ (HO)CH(CH ₃) ₂ CCl	CH ₃ MgBr	<i>i</i> -C ₃ H ₇ (CH ₃) ₂ COH	100
<i>n</i> -C ₃ H ₇ (CH ₃ O)CHCl (0.1 mole)	C ₆ H ₅ CH ₂ MgCl (0.1 mole C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ CH(OCH ₃)- <i>n</i> -C ₃ H ₇ (98x%); 2-CH ₃ C ₆ H ₄ CH(OCH ₃)- <i>n</i> -C ₃ H ₇ (2x%)	263
C₅H₁₁Br			
<i>i</i> -C ₅ H ₁₁ Br	<i>i</i> -C ₅ H ₁₁ MgBr	(<i>i</i> -C ₅ H ₁₁ —) ₂ (9%);* CH ₃ CH=C(CH ₃) ₂ ; C ₅ H ₁₀	212
(C ₂ H ₅) ₂ CHBr	(C ₂ H ₅) ₂ CHMgBr	[(C ₂ H ₅)CH=] ₂ (15%) [†] ; unidentified gases	212
(C ₂ H ₅) ₂ CHBr	C ₆ H ₅ MgBr	(C ₂ H ₅) ₂ CHC ₆ H ₅ (51%); (C ₆ H ₅ —) ₂	212
<i>t</i> -C ₅ H ₁₁ Br	<i>n</i> -C ₃ H ₇ MgBr	<i>t</i> -C ₅ H ₁₁ - <i>n</i> -C ₃ H ₇ (<i>ca.</i> 15%); C ₁₀ H ₂₂	212
<i>t</i> -C ₅ H ₁₁ Br (353 g.)	<i>n</i> -C ₄ H ₉ C≡CMgBr (246 g. C ₆ H ₁₀)	<i>t</i> -C ₅ H ₁₁ C≡C- <i>n</i> -C ₄ H ₉ (13 g., 3%)	287
C₅H₁₁I			
(C ₂ H ₅) ₂ CHI	C ₆ H ₅ MgBr	(C ₂ H ₅) ₂ CHC ₆ H ₅ (5.4%); C ₆ H ₆ ; C ₁₀ H ₂₂ ; (C ₆ H ₅ —) ₂	212
C₆Cl₆			
C ₆ Cl ₆	RMgX [‡]	No reaction	50
C₆Br₆			
C ₆ Br ₆	CH ₃ MgI	(CH ₃) ₆ C ₆	50

* Späth (212) did not attempt to distinguish between the 2,7-dimethyloctane formed during the preparation of the Grignard reagent and that (if any) formed subsequently.

[†] Späth (212) did not attempt to distinguish between the 3,4-diethylhexane formed during the preparation of the Grignard reagent and that (if any) formed subsequently.

[‡] RMgX = CH₃MgI, C₆H₅Br.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆Br₆ (cont.)			
C ₆ Br ₆ (10 g.)	C ₆ H ₅ MgBr (8.07 equiv.)	1,2,4,5-(C ₆ H ₅) ₄ C ₆ H ₂ (0.50 g.); 1,2,4,5-Br ₄ C ₆ H ₂ (0.20 g.)*	70,46,50
C₆I₆			
C ₆ I ₆	CH ₃ MgI	Mostly tar; trace (CH ₃) ₆ C ₆	50
C ₆ I ₆	C ₆ H ₅ MgBr	1,2,4,5-(C ₆ H ₅) ₄ C ₆ H ₂ [†]	50
C₆H₄Cl₂			
C ₆ H ₄ 1,2-Cl ₂ (1.5 g.)	4-CH ₃ OC ₆ H ₄ MgBr (5.6 g. C ₇ H ₇ BrO)	1,2-(<i>p</i> -CH ₃ OC ₆ H ₄) ₂ C ₆ H ₄ (ca. 50 mg.)	280
C₆H₅Br			
C ₆ H ₅ Br	CH ₃ MgBr + FeCl ₃ (trace)	C ₆ H ₅ CH ₃ (10%)	282
C ₆ H ₅ Br	C ₂ H ₅ MgBr (2 equiv.) + FeCl ₃ (trace)	C ₆ H ₅ MgBr; MgBr ₂ ; C ₂ H ₆ ; C ₂ H ₄	282
C ₆ H ₅ Br	C ₆ H ₅ MgBr	C ₆ H ₅ Br; (C ₆ H ₅ —) ₂ (13%) [‡]	212
C₆H₅I			
C ₆ H ₅ I (41 g.)	C ₆ H ₅ MgI (41 g. C ₆ H ₅ I)	(C ₆ H ₅ —) ₂ (2.5 g.) [§]	131

* Comparable yields of tetrabromoterephthalic acid were obtained upon carbonation of the reaction mixture and subsequent hydrolysis.

[†] This product is reported by Durand and Wai-Hsun (50) as (C₆H₅)₆C; *cf.*, however, Geissman and Mallat (70) and Dilthey and Hurtig (46).

[‡] Späth did not attempt to distinguish between the biphenyl formed in the preparation of the Grignard reagent and that (if any) formed subsequently. In control experiments conducted in connection with a study of the effects of metallic halides on the reactions of aryl Grignard reagents with organic halides, Kharasch and Fields, *J. Am. Chem. Soc.*, 63, 2316-20 (1941), found 6-8 percent of biphenyl in phenylmagnesium bromide preparations.

[§] See footnote to preceding entry.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₆H₆Cl₂ 4-ClC ₆ H ₄ CH ₂ Cl (3.5 g.)	C ₆ H ₅ CH ₂ (C ₁₂ H ₈ ⇒)CC(=C ₁₂ H ₈)MgCl* [†]	4-ClC ₆ H ₄ CH ₂ (C ₁₂ H ₈ ⇒)CC(=C ₁₂ H ₈)-CH ₂ C ₆ H ₅ * (1.69 g.)	66
C₆H₈Br₂ (—HC=CHCH ₂ Br) ₂	C ₂ H ₅ MgBr	<i>n</i> -C ₃ H ₇ CH=CHCH(C ₂ H ₅)CH=CH ₂ ; (<i>n</i> -C ₃ H ₇ CH=CH—) ₂ ; [H ₂ C=CH(C ₂ H ₅)CH—] ₂ ; C ₂ H ₅ (<i>n</i> -C ₃ H ₇)CHCH=CHCH=CH ₂ (?); BrCH ₂ (C ₂ H ₅)CHCH=CHCH=CH ₂ (?); + unidentified products	293
C₆H₉Cl CH ₃ C≡C(CH ₃) ₂ CCl (40 g.)	CH ₃ MgBr (52 g. CH ₃ Br)	[(CH ₃) ₂ C=] ₂ C (50%)	248
CH ₃ C≡C(CH ₃) ₂ CCl (40 g.)	C ₆ H ₅ MgBr (50 g. C ₆ H ₅ Br)	(CH ₃) ₂ C=C=C(CH ₃)C ₆ H ₅ (40%)	248
3-Chlorocyclohexene	CH ₃ MgBr	3-Methylcyclohexene	257
3-Chlorocyclohexene	C ₂ H ₅ MgBr	3-Ethylcyclohexene (15%); 3,3'-bicyclohexenyl (75%)	16
3-Chlorocyclohexene	RMgBr [‡]	3-R-cyclohexene (ca. 70%); [§] RH; bicyclohexenyl; 1,3-cyclohexadiene	288
C₆H₉X 3-Halocyclohexene	RMgX [¶]	3-R-cyclohexene	15

* (C₁₂H₈⇒) = *o*-biphenylene.[†] The Grignard reagent was prepared by the addition of C₆H₅CH₂MgCl to 3.28 g. of [(C₁₂H₈⇒)C=]₂.[‡] R = CH₃, C₂H₅, *n*-C₃H₇, *i*-C₃H₇, *n*-C₄H₉, C₆H₅, C₆H₅CH₂.[§] At -12° or 0°; at higher temperatures the proportion of "normal" product decreases and those of the byproducts increase.[¶] R = CH₃, C₂H₅, C₆H₅.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₀Br₂			
1,2-Dibromocyclohexane	<i>n</i> -C ₃ H ₅ MgBr	Cyclohexene; <i>n</i> -C ₆ H ₁₃	159
1,2-Dibromocyclohexane	(CH ₂) ₅ CHMgCl	Cyclohexene; bicyclohexyl (?)*	159
C₆H₁₁ClO			
CH ₃ O(CH ₂) ₂ CH=CHCH ₂ Cl (30 g.)	C ₆ H ₅ MgBr (35 g. C ₆ H ₅ Br)	CH ₃ OCH ₂ CH ₂ CH(C ₆ H ₅)CH=CH ₂ (7.7 g.); CH ₃ OCH ₂ CH ₂ CH=CHCH ₂ C ₆ H ₅ (17.0 g.)	175
CH ₃ OCH ₂ CH ₂ (H ₂ C=CH)CHCl (30 g.)	C ₆ H ₅ MgBr (35 g. C ₆ H ₅ Br)	CH ₃ OCH ₂ CH ₂ CH(C ₆ H ₅)CH=CH ₂ (8.8 g.); CH ₃ OCH ₂ CH ₂ CH=CHCH ₂ C ₆ H ₅ (15.5 g.)	175
CH ₃ OCH ₂ CH=C(CH ₃)CH ₂ Cl	R(CH ₃)(BrMgO)CC≡CMgBr [†]	CH ₃ OCH ₂ CH=C(CH ₃)CH ₂ C≡ CC(OH)(CH ₃)R [†]	164
2-Chlorocyclohexanol (27 g.)	CH ₃ MgI (60 g. CH ₃ I)	(CH ₂) ₄ CHCH(OH)CH ₃ [‡] (24 g., <i>ca.</i> 50%)	247
2-Chlorocyclohexanol	(CH ₂) ₅ CHMgCl	(CH ₂) ₄ CH[(CH ₂) ₅ CH]CHOH	224
2-Chlorocyclohexanol	C ₆ H ₅ CH ₂ MgCl	(CH ₂) ₄ CH(C ₆ H ₅ CH ₂)CHOH	269
C₆H₁₂ClN			
2-Chlorocyclohexylamine	C ₂ H ₅ MgBr	Recovered chloride (quant.) [§]	156
2-Chlorocyclohexylamine	C ₂ H ₅ MgBr	(CH ₂) ₅ CO (<i>ca.</i> quant.) [¶]	156
C₆H₁₂Cl₃N			
N(CH ₂ CH ₂ Cl) ₃ (1 mole)	H ₂ C=CHCH ₂ MgCl (3 moles)	N[(CH ₂) ₃ CH=CH ₂] ₃ (90%)	119

* The reaction is said to be analogous to that with *n*-C₃H₇MgBr.

[†] R = β-(2,6,6-Trimethyl-1-cyclohexenyl)vinyl.

[‡] This product was originally reported by Godchot and Bedos (75) as a mixture of *cis*- and *trans*-2-methylcyclohexanols.

[§] Combination in Et₂O solution.

[¶] Combination in Et₂O solution; distillation of Et₂O; fusion of residue.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₆H₁₂Br₂O			
BrCH ₂ (<i>n</i> -C ₄ H ₉ O)CHBr	<i>i</i> -C ₅ H ₁₁ MgBr (slight excess)	BrCH ₂ (<i>n</i> -C ₄ H ₉ O)CH- <i>i</i> -C ₅ H ₁₁ (65%)	51
C ₂ H ₅ CHBr(C ₂ H ₅ O)CHBr	H ₂ C=CHCH ₂ MgBr (slight excess)	C ₂ H ₅ CHBr(C ₂ H ₅ O)CHCH ₂ CH=CH ₂ (37-45%)	205
C ₂ H ₅ CHBr(C ₂ H ₅ O)CHBr	<i>n</i> -C ₃ H ₇ MgBr	C ₂ H ₅ CHBr(C ₂ H ₅ O)CH- <i>n</i> -C ₃ H ₇ (30-32%)	210
C ₂ H ₅ CHBr(C ₂ H ₅ O)CHBr	<i>i</i> -C ₃ H ₇ MgBr	C ₂ H ₅ CHBr(C ₂ H ₅ O)CH- <i>i</i> -C ₃ H ₇ (20-35%)	210
(CH ₃) ₂ CBr(C ₂ H ₅ O)CHBr	C ₂ H ₅ MgBr (10-30% excess)	(CH ₃) ₂ CBr(C ₂ H ₅ O)CHC ₂ H ₅ (49%)	202
BrCH ₂ (C ₂ H ₅)(C ₂ H ₅ O)CBr	C ₂ H ₅ MgBr (10-30% excess)	BrCH ₂ (C ₂ H ₅ O)C(C ₂ H ₅) ₂ (55%)	202
BrCH ₂ (C ₂ H ₅)(C ₂ H ₅ O)CBr	<i>n</i> -C ₈ H ₇ MgBr	BrCH ₂ (C ₂ H ₅)(C ₂ H ₅ O)C- <i>n</i> -C ₃ H ₇ (30%)	210
BrCH ₂ (C ₂ H ₅)(C ₂ H ₅ O)CBr	<i>i</i> -C ₃ H ₇ MgBr	BrCH ₂ (C ₂ H ₅)(C ₂ H ₅ O)C- <i>i</i> -C ₃ H ₇ (42%)	210
CH ₃ (CH ₃ CHBr)(C ₂ H ₅ O)CBr	C ₂ H ₅ MgBr	CH ₃ (CH ₃ CHBr)(C ₂ H ₅ O)CC ₂ H ₅ (40%)	210
CH ₃ (CH ₃ CHBr)(C ₂ H ₅ O)CBr	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (CH ₃ CHBr)(C ₂ H ₅ O)C- <i>n</i> -C ₃ H ₇ (26%)	210
CH ₃ (CH ₃ CHBr)(C ₂ H ₅ O)CBr	<i>i</i> -C ₃ H ₇ MgBr	CH ₃ (CH ₃ CHBr)(C ₂ H ₅ O)C- <i>i</i> -C ₃ H ₇ (22%)	210
C₆H₁₃Cl			
<i>i</i> -C ₃ H ₇ (CH ₃) ₂ CCl	CH ₃ MgCl	<i>i</i> -C ₃ H ₇ C(CH ₃) ₃	194
C₆H₁₃Br			
<i>n</i> -C ₃ H ₇ (CH ₃) ₂ CBr	CH ₃ MgI	"Impracticable"	45
C₆H₁₃BrO			
<i>n</i> -C ₅ H ₁₁ OCH ₂ Br	C ₂ H ₅ MgBr	<i>n</i> -C ₅ H ₁₁ O- <i>n</i> -C ₃ H ₇ (60-65%)	94
<i>n</i> -C ₅ H ₁₁ OCH ₂ Br	<i>n</i> -C ₅ H ₁₁ O(CH ₂) ₃ MgI	[<i>n</i> -C ₅ H ₁₁ O(CH ₂) ₂ —] ₂	95,97
<i>n</i> -C ₅ H ₁₁ OCH ₂ Br	<i>n</i> -C ₅ H ₁₁ O(CH ₂) ₄ MgI	[<i>n</i> -C ₅ H ₁₁ O(CH ₂) ₂] ₂ CH ₂	95,96,97
C₆H₁₄ClN			
(C ₂ H ₅) ₂ N(CH ₂) ₂ Cl	H ₂ C=CHCH ₂ MgCl	(C ₂ H ₅) ₂ N(CH ₂) ₃ CH=CH ₂ (85%)	119,120
(C ₂ H ₅) ₂ N(CH ₂) ₂ Cl	H ₂ C=C(CH ₃)CH ₂ MgCl	(C ₂ H ₅) ₂ N(CH ₂) ₃ C(CH ₃)=CH ₂ (75-80%)	119

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₇H₅Cl₃			
4-ClC ₆ H ₄ CHCl ₂ (31.5 g.)	CH ₃ MgCl	CH ₃ (4-ClC ₆ H ₄)CHCHClC ₆ H ₄ -4-Cl; (7.3 g., crude); [CH ₃ (4-ClC ₆ H ₄)CH—] ₂ ; 4-ClC ₆ H ₄ - <i>i</i> -C ₃ H ₇	54
C ₆ H ₅ CCl ₃	CH ₃ MgCl (0.2 M sol'n)	(C ₆ H ₅ CCl ₂ —) ₂	67
C ₆ H ₅ CCl ₃	CH ₃ MgCl (2.0 M sol'n)	(C ₆ H ₅ CCl=) ₂ * (22%)	67
C ₆ H ₅ CCl ₃	C ₂ H ₅ MgBr	(C ₆ H ₅ CCl ₂ —) ₂ ; (C ₆ H ₅ CCl=) ₂	191
C ₆ H ₅ CCl ₃	C ₆ H ₅ MgBr	(C ₆ H ₅ CCl ₂ —) ₂ ; (C ₆ H ₅ CCl=) ₂ ; [C ₆ H ₅ (C ₆ H ₅ CCl ₂)CCl—] ₂	191
C₇H₆Cl₂			
C ₆ H ₅ CHCl ₂ (25 g.)	CH ₃ MgCl	CH ₃ (C ₆ H ₅)CHCHClC ₆ H ₅ (5 g., crude); [CH ₃ (C ₆ H ₅)CH—] ₂ (2 forms); C ₆ H ₅ - <i>i</i> -C ₃ H ₇	54
C ₆ H ₅ CHCl ₂ (25 g.)	CH ₃ MgI (60 g. CH ₃ I)	(C ₆ H ₅ CHCl—) ₂ (4.3 g., crude); brown oil	67
C ₆ H ₅ CHCl ₂	C ₆ H ₅ MgBr	(C ₆ H ₅ CHCl—) ₂ ; (C ₆ H ₅ —) ₂ ; (C ₆ H ₅) ₃ CH	67
C ₆ H ₅ CHCl ₂ (20.6 g.)	C ₆ H ₅ MgBr (40.0 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ CH (ca. 21%); [(C ₆ H ₅) ₂ CH—] ₂ (0.7 g.)	186
C₇H₇Cl			
C ₆ H ₅ CH ₂ Cl (25 g.)	CH ₃ MgI (30 g. CH ₃ I)	C ₆ H ₅ C ₂ H ₅ (5 g., 23.8%) [†]	106
C ₆ H ₅ CH ₂ Cl (25 g.)	CH ₃ MgI (30 g. CH ₃ I)	C ₆ H ₅ C ₂ H ₅ (ca. 25%) [†]	106
C ₆ H ₅ CH ₂ Cl	CH ₃ MgI	4-C ₆ H ₅ CH ₂ C ₆ H ₄ CH ₂ CH ₂ C ₆ H ₅ [§] ; C ₆ H ₅ C ₂ H ₅ (37%); (C ₆ H ₅ CH ₂ —) ₂ (24%) [¶]	212

* *Cis* and *trans* isomers in the approximate ratio of 1:5.

[†] Dropwise addition of chloride to Grignard reagent solution; distillation of Et₂O.

[‡] Addition of chloride to Grignard reagent solution; addition of C₇H₈; distillation of Et₂O; one hour reflux.

[§] Späth (212) reported this product as 1,2,3-triphenylpropane; *cf.*, however, Fuson, *J. Am. Chem. Soc.*, 48, 2937-42 (1926).

[¶] Five hours reflux in Et₂O.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₇H₇Cl (cont.)			
C ₆ H ₅ CH ₂ Cl	CH ₃ MgI (excess)	C ₆ H ₅ C ₂ H ₅ (23-27%); (C ₆ H ₅ CH ₂ —) ₂ (31-33%); C ₂ H ₆ (33-35%)*	60
C ₆ H ₅ CH ₂ Cl	C ₂ H ₅ MgBr	C ₆ H ₅ - <i>n</i> -C ₃ H ₇ (70%); (C ₆ H ₅ CH ₂ —) ₂ ; C ₂ H ₆ ; C ₂ H ₄	19
C ₆ H ₅ CH ₂ Cl	<i>n</i> -C ₃ H ₇ MgBr	C ₆ H ₅ - <i>n</i> -C ₄ H ₉ (26%)	19
C ₆ H ₅ CH ₂ Cl	<i>n</i> -C ₄ H ₉ MgBr	C ₆ H ₅ - <i>n</i> -C ₅ H ₁₁ (47%)	19
C ₆ H ₅ CH ₂ Cl (46 g.)	<i>s</i> -C ₄ H ₉ MgBr (50 g. C ₄ H ₉ Br)	C ₆ H ₅ CH ₂ - <i>s</i> -C ₄ H ₉ (9.8 g., 18%)	261
C ₆ H ₅ CH ₂ Cl	C ₆ H ₅ CH ₂ MgCl	(C ₆ H ₅ CH ₂ —) ₂ (67.6%)†	239
C ₆ H ₅ CH ₂ Cl	2-Methylindolyl-MgI	2-Methyl-3-benzylindole; 2-methyl-3,3-dibenzylindole	105
C ₆ H ₅ CH ₂ Cl	(C ₆ H ₅) ₃ CMgBr	C ₆ H ₅ CH ₂ C(C ₆ H ₅) ₃ (90%)	10
C ₆ H ₅ CH ₂ Cl (2.78 g.)	4-ClC ₆ H ₄ CH ₂ (C ₁₂ H ₈ =)C-C(=C ₁₂ H ₈)MgCl‡§	4-ClC ₆ H ₄ CH ₂ (C ₁₂ H ₈ =)CC-(=C ₁₂ H ₈)CH ₂ C ₆ H ₅ † (0.37 g., 7%)	66
C ₆ H ₅ CH ₂ Cl (3.00 g.)	C ₆ H ₅ CH ₂ (C ₁₂ H ₈ =)C-C(=C ₁₂ H ₈)MgCl‡¶	[C ₆ H ₅ CH ₂ (C ₁₂ H ₈ =)C—] ₂ †	66
C₇H₇Br			
C ₆ H ₅ CH ₂ Br	CH ₃ MgI (excess)	C ₆ H ₅ C ₂ H ₅ (20-23%); (C ₆ H ₅ CH ₂ —) ₂ (34-37%); C ₂ H ₆ (36-38%)	60
C ₆ H ₅ CH ₂ Br	HC≡CMgBr	C ₆ H ₅ CH ₂ C≡CH (70%); (C ₆ H ₅ CH ₂ C≡) ₂ (8%); C ₂ H ₂ (12%)	90,196, 219

* Slow dropwise addition of chloride to ethereal Grignard reagent solution at 40-50°.

† Whitmore and Sloat (239) do not distinguish between the bibenzyl formed during the preparation of the Grignard reagent and that formed subsequently.

‡ (C₁₂H₈=) = *o*-biphenylene.

§ The Grignard reagent was prepared by the addition of 4-ClC₆H₄CH₂MgCl to 3.28 g. of [(C₁₂H₈=)C=].

¶ The Grignard reagent was prepared by the addition of C₆H₅CH₂MgCl to 3.28 g. of [(C₁₂H₈=)C=].

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₇Br (<i>cont.</i>)			
C ₆ H ₅ CH ₂ Br	9-Fluorenyl-MgBr	(C ₆ H ₅ CH ₂ —) ₂ (53%); 9,9'-bifluorenyl (85%)	155
C₇H₇I			
C ₆ H ₅ CH ₂ I	CH ₃ MgI (excess)	C ₆ H ₅ C ₂ H ₅ (10%); (C ₆ H ₅ CH ₂ —) ₂ (2%); C ₂ H ₆ (40%)	60
C ₆ H ₅ CH ₂ I	C ₂ H ₅ MgI	C ₆ H ₅ - <i>n</i> -C ₃ H ₇ (10.5%); 4-C ₆ H ₅ CH ₂ C ₆ H ₄ CH ₂ CH ₂ C ₆ H ₅ *	212
C₇H₁₁Cl			
3-Chloro-5-methylcyclohexene	CH ₃ MgI	3,5-Dimethylcyclohexene	158
C₇H₁₁Br			
1-Methyl-6-bromocyclohexene	CH ₃ MgBr	1,6-Dimethylcyclohexene	93
C₇H₁₁I			
<i>n</i> -C ₅ H ₁₁ C≡CI	<i>n</i> -C ₅ H ₁₁ C≡CMgI	(<i>n</i> -C ₅ H ₁₁ C≡C—) ₂	91
C₇H₁₃Cl			
<i>cis</i> -1-Chloro-2-methylcyclohexane	CH ₃ MgBr	46% reaction; 1,2-dimethylcyclohexane (10%); methylcyclohexene (33%); CH ₄	118
<i>trans</i> -1-Chloro-2-methylcyclohexane	CH ₃ MgBr	49% reaction; 1,2-dimethylcyclohexane (10%); methylcyclohexene (34%); CH ₄	118
C₇H₁₃ClO			
C ₂ H ₅ OCH ₂ CH ₂ CH=CHCH ₂ Cl (40.0 g.)	C ₂ H ₅ MgBr (37.0 g. C ₂ H ₅ Br)	Recovered C ₇ H ₁₃ ClO (7.4 g.); C ₂ H ₅ OCH ₂ CH ₂ CH=CH- <i>n</i> -C ₃ H ₇ (16.8 g.); H ₂ C=CH(C ₂ H ₅ OCH ₂ CH ₂)- (C ₂ H ₅ OCH ₂ CH ₂ CH=CHCH ₂)CH (7.1 g.)	289

* Späth (212) reported this product as 1,2,3-triphenylpropane; *c/f.*, however, Fuson, *J. Am. Chem. Soc.*, 48, 2937-42 (1926).

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₇H₁₃ClO (<i>cont.</i>)			
C ₂ H ₅ OCH ₂ CH ₂ CH=CHCH ₂ Cl (30.0 g.)	<i>n</i> -C ₄ H ₉ MgBr (35.9 g. C ₄ H ₉ Br)	Recovered C ₇ H ₁₃ ClO (3.6 g.); C ₂ H ₅ OCH ₂ CH ₂ CH=CH- <i>n</i> -C ₅ H ₁₁ (18.7 g.); H ₂ C=CH(C ₂ H ₅ OCH ₂ CH ₂)- (C ₂ H ₅ OCH ₂ CH ₂ CH=CHCH ₂)CH (5.5 g.)	289
H ₂ C=CH(C ₂ H ₅ OCH ₂ CH ₂)CHCl (40.0 g.)	C ₂ H ₅ MgBr (37.0 C ₂ H ₅ Br)	Recovered C ₇ H ₁₃ ClO (2.0 g.); C ₂ H ₅ OCH ₂ CH ₂ CH=CH- <i>n</i> -C ₃ H ₇ (18.9 g.); H ₂ C=CH(C ₂ H ₅ OCH ₂ CH ₂)- (C ₂ H ₅ OCH ₂ CH ₂ CH=CHCH ₂)CH (8.2 g.)	289
H ₂ C=CH(C ₂ H ₅ OCH ₂ CH ₂)CHCl (30.0 g.)	<i>n</i> -C ₄ H ₉ MgBr (35.9 g. C ₄ H ₉ Br)	Recovered C ₇ H ₁₃ ClO (3.4 g.); C ₂ H ₅ OCH ₂ CH ₂ CH=CH- <i>n</i> -C ₅ H ₁₁ (18.3 g.); H ₂ C=CH(C ₂ H ₅ OCH ₂ CH ₂)- (C ₂ H ₅ OCH ₂ CH ₂ CH=CHCH ₂)CH (6.3 g.)	289
2-Chloro-3-methylcyclohexanol	<i>i</i> -C ₃ H ₇ MgBr	"Menthol" (allophanate, m 133°)	265
2-Chloro-5-methylcyclohexanol, b. ₁₄ 95-97° (40 g.)	CH ₃ MgI (80 g. CH ₃ I)	2,5-Dimethylcyclohexanol* (60%)	76,74
2-Chloro-5-methylcyclohexanol, b. ₁₄ 103-105° (40 g.)	CH ₃ MgI (80 g. CH ₃ I)	2,5-Dimethylcyclohexanol (2 forms) (50%)	76,74
2-Chloro-5-methylcyclohexanol, "liquid isomer"	CH ₃ MgI	2,5-Dimethylcyclohexanone (semi- carbazone, m. 155°)	268
2-Chloro-5-methylcyclohexanol, "solid isomer"	CH ₃ MgI	2,5-Dimethylcyclohexanone (semi- carbazone, m. 122°)	268
2-Chloro-5-methylcyclohexanol, b. ₁₄ 95-97°	<i>i</i> -C ₃ H ₇ MgBr	Isomeric menthols (allophanates, m. 133° and 177°)	267
2-Chloro-5-methylcyclohexanol, b. ₁₄ 103-105°	<i>i</i> -C ₃ H ₇ MgBr	Isomeric menthols (allophanates, m. 133° and 177°)	267
2-Chlorocycloheptanol	CH ₃ MgI (2 equiv.)	(CH ₂) ₅ CHCH(CH ₃)OH (chiefly); (CH ₂) ₅ C=CHCH ₃	77,264,4

* Two stereoisomers; the allophanates melt, respectively, at 125° and 157-158°.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₇H₁₃ClO (<i>cont.</i>)			
2-Chlorocycloheptanol	C ₂ H ₅ MgBr	(CH ₂) ₅ CHCH(C ₂ H ₅)OH	4
2-Chlorocycloheptanol	C ₆ H ₅ MgBr	(CH ₂) ₅ CHCH(C ₆ H ₅)OH	264,4
C₇H₁₃Br			
(CH ₃) ₂ C=CHC(CH ₃) ₂ Br	<i>i</i> -C ₃ H ₇ MgBr	(CH ₃) ₂ C=CH(CH ₃) ₂ C- <i>i</i> -C ₃ H ₇ (25%)	145
(CH ₃) ₂ C=CHC(CH ₃) ₂ Br	<i>n</i> -C ₄ H ₉ MgBr (excess)	(CH ₃) ₂ C=CHC(CH ₃) ₂ - <i>n</i> -C ₄ H ₉ (30%)	255
(CH ₃) ₂ C=CHC(CH ₃) ₂ Br	<i>i</i> -C ₄ H ₉ MgBr	(CH ₃) ₂ C=CHC(CH ₃) ₂ - <i>i</i> -C ₄ H ₉ (30%)	255
(CH ₃) ₂ C=CHC(CH ₃) ₂ Br	<i>i</i> -C ₅ H ₁₁ MgBr	(CH ₃) ₂ C=CH(CH ₃) ₂ C- <i>i</i> -C ₅ H ₁₁ (30%)	145
(CH ₃) ₂ C=CHC(CH ₃) ₂ Br	C ₆ H ₅ MgBr	(CH ₃) ₂ C=CH(CH ₃) ₂ CC ₆ H ₅ (26%)	145
C₇H₁₄ClN			
1-Chloro-2-methylaminocyclohexane	C ₂ H ₅ MgBr	(CH ₂) ₅ CO; CH ₃ NH ₂	156
1-Chloro-2-amino-4-methylcyclohexane	C ₂ H ₅ MgBr	3-Methylcyclohexanone	156
2-Chloro-2-methylcyclohexylamine	C ₂ H ₅ MgBr	2-Methylcyclohexanone	156
C₇H₁₅Cl			
<i>t</i> -C ₄ H ₉ (CH ₃) ₂ CCl	CH ₃ MgCl	(<i>t</i> -C ₄ H ₉ —) ₂ (48%)	32
C₇H₁₅Br			
<i>t</i> -C ₄ H ₉ (CH ₃) ₂ CBr (16 g.)	CH ₃ MgBr	(<i>t</i> -C ₄ H ₉ —) ₂ (3 g.)	101
C₈H₅Br			
C ₆ H ₅ C≡CBr (18 g., 0.097 mole)	CH ₃ MgBr (0.16 mole)	C ₆ H ₅ C≡CH (8.8 g., 89%); CH ₃ Br	121
C₈H₅I			
C ₆ H ₅ C≡CI	C ₆ H ₅ C≡CMgI	(C ₆ H ₅ C≡C—) ₂	91

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₈H₆Cl₂O			
ClOC(C ₆ H ₅)CHCl (34 g.)	C ₆ H ₅ MgBr (170 g. C ₆ H ₅ Br)	HO(C ₆ H ₅) ₂ CCH(C ₆ H ₅) ₂ (14.5 g.)*	26
ClOC(C ₆ H ₅)CHCl (15 g.)	C ₆ H ₅ MgBr (75 g. C ₆ H ₅ Br)	C ₆ H ₅ COCH(C ₆ H ₅) ₂ (3 g.) [†]	26
C₈H₆BrN			
2-NCC ₆ H ₄ CH ₂ Br	CH ₃ MgI	(2-NCC ₆ H ₄ CH ₂ —) ₂ (40%)	59
2-NCC ₆ H ₄ CH ₂ Br	C ₂ H ₅ MgI	(2-NCC ₆ H ₄ CH ₂ —) ₂ (42.5%)	59
C₈H₆IN			
2-NCC ₆ H ₄ CH ₂ I [†]	CH ₃ MgI	(2-NCC ₆ H ₄ CH ₂ —) ₂ (25%)	59
2-NCC ₆ H ₄ CH ₂ I	C ₂ H ₅ MgI	(2-NCC ₆ H ₄ CH ₂ —) ₂ (25%)	59
C₈H₇ClO₂			
DL-HO ₂ C(C ₆ H ₅)CHCl	CH ₃ MgI (4 equiv.) [§]	β-[HO ₂ C(C ₆ H ₅)CH—] ₂ ; α-[HO ₂ C(C ₆ H ₅)CH—] ₂ ; C ₆ H ₅ CH(OH)CO ₂ H; recovered acid	152
DL-HO ₂ C(C ₆ H ₅)CHCl	C ₆ H ₅ MgBr (4 equiv.)	HO(C ₆ H ₅) ₂ CCH(OH)C ₆ H ₅ (10–20%); (C ₆ H ₅) ₂ CHCO ₂ H (1–8%); β-[HO ₂ C(C ₆ H ₅)CH—] ₂ (5–13%); α-[HO ₂ C(C ₆ H ₅)CH—] ₂ (1%)	152
L(–)-HO ₂ C(C ₆ H ₅)CHCl (30 g.)	C ₆ H ₅ MgBr (4 equiv.)	D(–)-HO(C ₆ H ₅) ₂ CCH(OH)C ₆ H ₅ (1.6 g.); β-[HO ₂ C(C ₆ H ₅)CH—] ₂ (1.0 g.); (C ₆ H ₅) ₂ CHCO ₂ H (3.1 g.); α-[HO ₂ C(C ₆ H ₅)CH—] ₂ (0.2 g.)	152

* Gradual (half-hour) addition of Et₂O-chloride solution to Grignard reagent solution; five and one-half hours reflux.

[†] Slow (one and one-half hour) addition of Grignard reagent solution to Et₂O-chloride solution.

[‡] The *para* isomer yielded an amorphous product containing halogen but no nitrogen.

[§] Experiments employing two, three, six, and seven equivalents of Grignard reagent were also carried out.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₆H₇Br			
C ₆ H ₅ CH=CHBr	CH ₃ MgI	C ₆ H ₅ CH=CHCH ₃ ("poor yield")	220,221
C₆H₇BrO₂			
DL-HO ₂ C(C ₆ H ₅)CHBr (12.5 g.)	C ₆ H ₅ MgBr (4 equiv.)	β-[HO ₂ C(C ₆ H ₅)CH—] ₂ (1.9 g.); α-[HO ₂ C(C ₆ H ₅)CH—] ₂ (1.8 g.); (C ₆ H ₅) ₂ CHCO ₂ H; (C ₆ H ₅ —) ₂ ; C ₆ H ₅ OH; HO(C ₆ H ₅) ₂ CCH(OH)C ₆ H ₅	152
C₈H₉ClO			
3-CH ₃ OC ₆ H ₄ CH ₂ Cl	<i>n</i> -C ₄ H ₉ MgCl	3-CH ₃ OC ₆ H ₄ - <i>n</i> -C ₅ H ₁₁ (17%)	3
C₈H₉BrO			
C ₆ H ₅ OCH ₂ CH ₂ Br	<i>n</i> -C ₅ H ₁₁ MgBr	C ₆ H ₅ OH; <i>n</i> -C ₅ H ₁₁ OH	85
C ₆ H ₅ OCH ₂ CH ₂ Br	C ₆ H ₅ MgBr	C ₆ H ₅ OCH ₂ CH ₂ C ₆ H ₅ (83%); C ₆ H ₅ OH	85
C ₆ H ₅ OCH ₂ CH ₂ Br	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ O(CH ₂) ₃ C ₆ H ₅ ("a little"); C ₆ H ₅ OH; C ₆ H ₅ CH ₂ OH	85
2-CH ₃ OC ₆ H ₄ CH ₂ Br	C ₂ H ₅ MgCl	2-CH ₃ OC ₆ H ₄ - <i>n</i> -C ₃ H ₇ (34.5%); (2-CH ₃ OC ₆ H ₄ CH ₂ —) ₂ ; 2-CH ₃ OC ₆ H ₄ CH ₃	212
2-CH ₃ OC ₆ H ₄ CH ₂ Br	C ₂ H ₅ MgBr	2-CH ₃ OC ₆ H ₄ - <i>n</i> -C ₃ H ₇ (32.6%); 2-CH ₃ OC ₆ H ₄ CH ₃ ; (2-CH ₃ OC ₆ H ₄ CH ₂ —) ₂	212
2-CH ₃ OC ₆ H ₅ CH ₂ Br	C ₂ H ₅ MgI	2-CH ₃ OC ₆ H ₄ - <i>n</i> -C ₃ H ₇ (9.7%); (2-CH ₃ OC ₆ H ₄ CO ₂ —) ₂	212
2-CH ₃ OC ₆ H ₄ CH ₂ Br	C ₆ H ₅ MgBr	2-CH ₃ OC ₆ H ₄ CH ₂ C ₆ H ₅ (60%)	212
3-CH ₃ OC ₆ H ₄ CH ₂ Br	CH ₃ MgBr	C ₂ H ₆ (67.6%); 3-CH ₃ OC ₆ H ₄ C ₂ H ₅ (34.1%)	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	CH ₃ MgBr	4-CH ₃ OC ₆ H ₄ C ₂ H ₅ (90%)	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	CH ₃ MgI	4-CH ₃ OC ₆ H ₄ C ₂ H ₅ (13.5%); (4-CH ₃ OC ₆ H ₅ CH ₂ —) ₂	212

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₈H₉BrO (cont.)			
4-CH ₃ OC ₆ H ₄ CH ₂ Br	C ₂ H ₅ MgCl	4-CH ₃ OC ₆ H ₄ - <i>n</i> -C ₃ H ₇ (88%); (4-CH ₃ OC ₆ H ₄ CH ₂ —) ₂	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	C ₂ H ₅ MgBr	4-CH ₃ OC ₆ H ₄ - <i>n</i> -C ₃ H ₇ (85%); (4-CH ₃ OC ₆ H ₄ CH ₂ —) ₂	212
4-CH ₃ OC ₆ H ₅ CH ₂ Br	C ₂ H ₅ MgI	4-CH ₃ OC ₆ H ₄ - <i>n</i> -C ₃ H ₇ (26.8%); (4-CH ₃ OC ₆ H ₄ CH ₂ —) ₂ ("a little")	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	<i>n</i> -C ₃ H ₇ MgBr	4-CH ₃ OC ₆ H ₄ - <i>n</i> -C ₄ H ₉ (68.3%); (4-CH ₃ OC ₆ H ₄ CH ₂ —) ₂ ("a little")	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	<i>i</i> -C ₃ H ₇ MgCl	4-CH ₃ OC ₆ H ₄ - <i>i</i> -C ₄ H ₉ (30.6%); (4-CH ₃ OC ₆ H ₄ CH ₂ —) ₂ ("a little"); 4-CH ₂ OC ₆ H ₄ CH ₃ (?)	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	<i>i</i> -C ₃ H ₇ MgBr	4-CH ₃ OC ₆ H ₄ - <i>i</i> -C ₄ H ₉ (29.8%); (4-CH ₃ OC ₆ H ₄ CH ₂ —) ₂ ("a little"); 4-CH ₃ OC ₆ H ₄ CH ₃	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	<i>i</i> -C ₄ H ₉ MgBr	4-CH ₃ OC ₆ H ₄ - <i>i</i> -C ₅ H ₁₁ (50%); (4-CH ₃ OC ₆ H ₄ CH ₂ —) ₂ ("a little")	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	<i>t</i> -C ₄ H ₉ MgCl	4-CH ₃ OC ₆ H ₄ CH ₂ C(CH ₃) ₃ (24.9%); (4-CH ₃ OC ₆ H ₄ CH ₂ —) ₂ ; 4-CH ₃ OC ₆ H ₄ CH ₃	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	<i>i</i> -C ₅ H ₁₁ MgBr	4-CH ₃ OC ₆ H ₄ - <i>i</i> -C ₆ H ₁₃ (50%); (<i>i</i> -C ₅ H ₁₁ —) ₂ ; (4-CH ₃ OC ₆ H ₄ CH ₂ —) ₂	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	(C ₂ H ₅) ₂ CHMgBr	4-CH ₃ OC ₆ H ₄ CH ₂ CH(C ₂ H ₅) ₂ (50%); (4-CH ₃ OC ₆ H ₄ CH ₂ —) ₂	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	(C ₂ H ₅) ₂ CHMgI	4-CH ₃ OC ₆ H ₄ CH ₂ CH(C ₂ H ₅) ₂ ("a little"); [(C ₂ H ₅) ₂ CH—] ₂	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	C ₆ H ₅ MgBr	4-CH ₃ OC ₆ H ₄ CH ₂ C ₆ H ₅ (60%)	212
4-CH ₃ OC ₆ H ₄ CH ₂ Br	C ₆ H ₅ MgI	4-CH ₃ OC ₆ H ₄ CH ₂ C ₆ H ₅ ("a little"); (4-CH ₃ OC ₆ H ₄ CH ₂ —) ₂ (?)	212

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₈H₉IO			
C ₆ H ₅ CH(OH)CH ₂ I	CH ₃ MgI (2 equiv.)	Recovered iodide (85%)*	79
C ₆ H ₅ CH(OH)CH ₂ I	CH ₃ MgI (2 equiv.)	CH ₃ (C ₆ H ₅ CH ₂)CHOH (42%) [†]	79
HOCH ₂ (C ₆ H ₅)CHI	CH ₃ MgI (2 equiv.)	CH ₃ (C ₆ H ₅ CH ₂)CHOH (9.8%); recovered iodide (6.4%)*	79
HOCH ₂ (C ₆ H ₅)CHI	CH ₃ MgI (2 equiv.)	CH ₃ (C ₆ H ₅ CH ₂)CHOH (56%) [†]	79
C₈H₁₀Br₂O			
C ₈ H ₁₀ Br ₂ O [‡]	C ₂ H ₅ MgBr	CH ₃ COC ₆ H ₅	157
C₈H₁₂Br₂O			
C ₈ H ₁₂ Br ₂ O [§]	C ₂ H ₅ MgBr	C ₆ H ₅ OH	157
C₈H₁₃Cl			
CH ₃ (C ₂ H ₅)(C ₂ H ₅ C≡C)CCl	CH ₃ MgBr	C ₂ H ₅ C≡C- <i>t</i> -C ₅ H ₁₁ (66%)	287
CH ₃ (C ₂ H ₅)(C ₂ H ₅ C≡C)CCl	C ₂ H ₅ MgBr	C ₂ H ₅ C≡CC(C ₂ H ₅) ₂ CH ₃ (61%)	287
C₈H₁₄ClO			
1,4-Dimethyl-3-chlorocyclohexanol	C ₂ H ₅ MgBr	1-Acetyl-3-methylcyclopentane; 2,4-dimethylcyclohexanone	222
C₈H₁₅Cl			
1-Chloro-1,3-dimethylcyclopentane (308 parts)	CH ₃ MgI (356 parts CH ₃ I)	1,1,3-Trimethylcyclopentane (19.3%)	153

* Addition of iodide to cooled, stirred Grignard reagent solution; spontaneous warming to room temperature.

[†] Addition of Et₂O-iodide solution to cooled, stirred Grignard reagent solution; spontaneous warming to room temperature; distillation of Et₂O on water-bath.

[‡] The dibromo derivative obtained upon treatment of 1-acetylcyclohexene with *N*-bromosuccinimide.

[§] The dibromo derivative obtained upon treatment of 3-ethoxycyclohexene with *N*-bromosuccinimide.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₈H₁₆Cl₂O			
Cl(CH ₃) ₂ C(<i>i</i> -C ₄ H ₉ O)CHCl	CH ₃ MgBr (excess)	(CH ₃) ₂ C = C(O- <i>i</i> -C ₄ H ₉)CH ₃	100,102
C₈H₁₆Br₂O			
C ₂ H ₅ CHBr(<i>n</i> -C ₄ H ₉ O)CHBr	<i>n</i> -C ₆ H ₁₃ MgBr	C ₂ H ₅ CHBr(<i>n</i> -C ₄ H ₉ O)CH- <i>n</i> -C ₆ H ₁₃	122
C₈H₁₇Br			
CH ₃ (<i>n</i> -C ₆ H ₁₃)CHBr	C ₂ H ₅ MgBr	CH ₃ (<i>n</i> -C ₆ H ₁₃)CHC ₂ H ₅ (7.9%); C ₂ H ₆ (53.8%); C ₂ H ₄ (38.3%)*	212
CH ₃ (<i>n</i> -C ₆ H ₁₃)CHBr	C ₂ H ₅ MgBr	C ₈ H ₁₆ (21.2%); (<i>s</i> -C ₈ H ₁₇ —) ₂ [†]	212
(+)-CH ₃ (<i>n</i> -C ₆ H ₁₃)CHBr, [α] _D ²⁴ + 30.03 [‡] (13.5 g., 0.070 mole)	H ₂ C = CHCH ₂ MgBr (60.5 g., 0.50 mole C ₃ H ₇ Br)	CH ₃ (<i>n</i> -C ₆ H ₁₃)CHCH ₂ CH = CH ₂ , [α] _D ²⁵ + 4.79 [§]	286
CH ₃ (<i>n</i> -C ₆ H ₁₃)CHBr	<i>n</i> -C ₃ H ₇ MgBr	C ₈ H ₁₈ (22.1%); C ₈ H ₁₆ (18.0%); C ₁₆ H ₃₄ (29.0%)	212
CH ₃ (<i>n</i> -C ₆ H ₁₃)CHBr	<i>t</i> -C ₄ H ₉ MgCl	CH ₃ (<i>n</i> -C ₆ H ₁₃)CH- <i>t</i> -C ₄ H ₉ (3.0%); [CH ₃ (<i>n</i> - C ₆ H ₁₃)CH—] ₂ (14.0%); C ₈ H ₁₆ (18.6%); C ₈ H ₁₈ (24.1%)	212
C₈H₁₇I			
CH ₃ (<i>n</i> -C ₆ H ₁₃)CHI	CH ₃ MgI	<i>n</i> -C ₆ H ₁₃ (CH ₃) ₂ CH (37.4%); CH ₄ ("much"); C ₂ H ₆ ("little")	212

* Addition of bromide to concentrated Grignard reagent solution; several hours at 100–105°.

† Addition of bromide to cooled concentrated Grignard reagent solution; three and one-half hours reflux.

‡ The highest reported rotation for the pure enantiomorph is [α]_D²⁵ + 34.3; it is estimated that the upper limit of the specific rotation is [α]_D + 38.1.

§ It is calculated that the specific rotation for the pure enantiomorph should be [α]_D + 7.0.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₉Cl			
C ₆ H ₅ CH=CHCH ₂ Cl (20 g., 0.13 mole)	CH ₃ MgBr (0.23 mole)	C ₆ H ₅ CH=CHC ₂ H ₅ (89%); (C ₆ H ₅ CH=CHCH ₂ —) ₂ (1%); C ₆ H ₅ CH=CHCH ₂ CH(C ₆ H ₅)CH=CH ₂ (5%)	121
C₉H₉ClO			
C ₆ H ₅ COCH ₂ CH ₂ Cl	C ₆ H ₅ MgBr	C ₆ H ₅ COCH ₂ CH ₂ C ₆ H ₅	235
C₉H₉Br			
C ₆ H ₅ CH=CHCH ₂ Br	C ₂ H ₅ MgBr	C ₆ H ₅ CH=CH- <i>n</i> -C ₃ H ₇ (ca. 50%); C ₂ H ₅ (C ₆ H ₅)CHCH=CH ₂ (ca. 25%)*	174
C ₆ H ₅ CH=CHCH ₂ Br (1.5 mole)	C ₂ H ₅ MgBr (1.5 mole)	C ₂ H ₅ Br (14.0%); C ₆ H ₅ CH=CHCH ₃ (2.5%); C ₆ H ₅ CH ₂ CH=CH ₂ (2.5%); (C ₆ H ₅ CH=CHCH ₂ —) ₂ (4.5%); C ₆ H ₅ CH=CHCH ₂ CH(C ₆ H ₅)CH=CH ₂ (4.5%); C ₂ H ₆ (10.0%); C ₂ H ₅ (C ₆ H ₅)CHCH=CH ₂ (23.0%); C ₆ H ₅ CH=CH- <i>n</i> -C ₃ H ₇ (50.0%); cond'n products (3.0%) [†]	173
C₉H₁₀ClBrMgO			
CH ₃ (C ₆ H ₅)(BrMgO)CCH ₂ Cl	C ₆ H ₅ MgBr	CH ₃ (C ₆ H ₅)C=CHC ₆ H ₅	221
C₉H₁₁ClO₂			
2,3-(CH ₃ O) ₂ C ₆ H ₃ CH ₂ Cl (0.08 mole)	<i>n</i> -C ₁₄ H ₂₉ MgBr (0.25 mole C ₁₄ H ₂₉ Br)	2,3-(CH ₃ O) ₂ C ₆ H ₃ - <i>n</i> -C ₁₅ H ₃₁ (25%); <i>n</i> -C ₂₈ H ₅₈ (ca. 5 g.)	151

* Slow addition of Et₂O-bromide solution to Grignard reagent solution; several hours reflux.[†] Addition of bromide to Grignard reagent solution; twelve hours at room temperature.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₉H₁₁ClO₂ (cont.)			
2,3-(CH ₃ O) ₂ C ₆ H ₃ CH ₂ Cl (14.9 g.)	<i>n</i> -C ₁₄ H ₂₉ MgBr (69.3 g. C ₁₄ H ₂₉ Br)	2,3-(CH ₃ O) ₂ C ₆ H ₃ - <i>n</i> -C ₁₅ H ₃₁ (2.0 g., 7.2%); <i>n</i> -C ₂₈ H ₅₈ (10.5 g.); [2,3-(CH ₃ O) ₂ C ₆ H ₃ CH ₂ —] ₂ (1.0 g.)	151
C₉H₁₁Br			
C ₂ H ₅ (C ₆ H ₅)CHBr	C ₂ H ₅ MgBr	C ₆ H ₅ (C ₂ H ₅) ₂ CH (22%); [C ₂ H ₅ (C ₆ H ₅)CH—] ₂	212
C₉H₁₅Cl			
<i>n</i> -C ₄ H ₉ C≡C(CH ₃) ₂ CCl	CH ₃ MgBr	<i>n</i> -C ₄ H ₉ C≡C- <i>t</i> -C ₄ H ₉ (74%)	287
<i>n</i> -C ₄ H ₉ C≡C(CH ₃) ₂ CCl (79.3 g., 0.5 mole)	C ₂ H ₅ MgBr (70.0 g. C ₂ H ₅ Br)	<i>n</i> -C ₄ H ₉ C≡C- <i>t</i> -C ₅ H ₁₁ (60%)	287
C₉H₁₇Cl			
<i>i</i> -C ₄ H ₉ CH=CH(CH ₃) ₂ CCl + <i>i</i> -C ₃ H ₇ [(CH ₃) ₂ C=CH]CHCl	CH ₃ MgCl	<i>i</i> -C ₄ H ₉ CH=CH- <i>t</i> -C ₄ H ₉ (1 part); <i>i</i> -C ₃ H ₇ [(CH ₃) ₂ C=CH]CHCH ₃ (5 parts)	98
C₉H₁₇ClO			
<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CHCH ₂ Cl (40.0 g.)	<i>n</i> -C ₄ H ₉ MgBr (40.3 g. C ₄ H ₉ Br)	Recovered C ₉ H ₁₇ ClO (5.2 g.); <i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CH- <i>n</i> -C ₅ H ₁₁ (19.6 g.); H ₂ C=CH(<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂)(<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CHCH ₂)CH (7.4 g.)	289
<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CHCH ₂ Cl (40.0 g.)	C ₆ H ₅ MgBr (49.8 g. C ₆ H ₅ Br)	Recovered C ₉ H ₁₇ ClO (5.0 g.); C ₆ H ₆ (2.7 g.); <i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CHCH ₂ C ₆ H ₅ (32.6 g.)	289
H ₂ C=CH(<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂)CHCl (40.0 g.)	<i>n</i> -C ₄ H ₉ MgBr (40.3 g. C ₄ H ₉ Br)	Recovered C ₉ H ₁₇ ClO (5.5 g.); <i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CH- <i>n</i> -C ₅ H ₁₁ (19.8 g.); H ₂ C=CH(<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂)(<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CHCH ₂)CH (7.4 g.)	289

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₉H₁₇ClO (<i>cont.</i>)			
H ₂ C=CH(<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂)CHCl (40.0 g.)	C ₆ H ₅ MgBr (49.8 g. C ₆ H ₅ Br)	Recovered C ₉ H ₁₇ ClO (5.8 g.); C ₆ H ₆ (2.0 g.); 289 <i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CHCH ₂ C ₆ H ₅ (33.3 g.)	
C₁₀H₇Br			
1-C ₁₀ H ₇ Br	CH ₃ MgBr + FeCl ₃ (trace)	1-C ₁₀ H ₇ CH ₃ (50%)	282
2-C ₁₀ H ₇ Br	CH ₃ MgBr + FeCl ₃ (trace)	2-C ₁₀ H ₇ CH ₃ (22%)	282
C₁₀H₁₃Cl			
4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ Cl	C ₂ H ₅ MgBr	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ - <i>n</i> -C ₃ H ₇ (50%)	19
2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂ Cl	CH ₃ MgI	[2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂ —] ₂ (86%)	64
2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂ Cl	2-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂]C ₆ H ₄ MgBr	1,2-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂] ₂ C ₆ H ₄	64,68
C₁₀H₁₃Br			
C ₆ H ₅ CH ₂ (CH ₃) ₂ CBr	C ₂ H ₅ CH ₂ MgCl (2 equiv.)	C ₆ H ₅ CH=C(CH ₃) ₂ ; (CH ₃) ₂ C(CH ₂ C ₆ H ₅) ₂	223
CH ₃ (C ₂ H ₅)(C ₆ H ₅)CBr	CH ₃ MgBr	C ₂ H ₅ (C ₆ H ₅)C(CH ₃) ₂ (36%)	212
C₁₀H₁₇Cl			
CH ₃ (C ₂ H ₅)(<i>n</i> -C ₄ H ₉ C≡C)CCl	CH ₃ MgBr	<i>n</i> -C ₄ H ₉ C≡C- <i>t</i> -C ₅ H ₁₁ (73%)	287
Bornyl chloride	CH ₃ MgBr	5% reaction during 28 hrs. reflux	118
Iosbornyl chloride	CH ₃ MgBr	90% reaction during 1 hr. reflux: bornylene (90%); CH ₄	118
(+)- α -Pinene hydrochloride	C ₁₀ H ₁₇ MgCl*	Camphane (39.5%); bornylene (39.5%); bibornyl (21.0%)	188

* From (+)- α -pinene hydrochloride; Rivière (188) concludes that this Grignard reagent is an equimolecular mixture of bornyl- and isobornylmagnesium chlorides.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₇Cl (<i>cont.</i>)			
(+)- α -Pinene hydrochloride	"Isomerized" C ₁₀ H ₁₇ MgCl*	Camphane (17.5%); bornylene (17.5%); bibornyl (65.0%)	188
C₁₀H₁₉Cl			
CH ₃ (C ₂ H ₅)(<i>n</i> -C ₅ H ₁₁ C \equiv C)CCl 1-Chloromethoxy-4- <i>n</i> - propylcyclohexane (9.5 g.)	CH ₃ MgBr CH ₃ MgI (8.0 g. CH ₃ I)	<i>n</i> -C ₅ H ₁₁ C \equiv C- <i>t</i> -C ₅ H ₁₁ (72%) 1-Ethoxy-4- <i>n</i> -propylcyclohexane (8.5 g., 82%)	287 69
C₁₀H₁₉Br₂Cl			
Cl(CH ₂) ₇ CHBr(CH ₃ O)CHBr	<i>n</i> -C ₈ H ₁₇ MgBr (<i>ca.</i> 1.3 equiv.)	Cl(CH ₂) ₇ CHBr(CH ₃ O)CH- <i>n</i> -C ₈ H ₁₇	12
C₁₁H₉Br			
1-C ₁₀ H ₇ CH ₂ Br	1-C ₁₀ H ₇ MgBr	(1-C ₁₀ H ₇ —) ₂	197
C₁₁H₁₂Cl₂			
2,4,6-(CH ₃) ₃ C ₆ H ₂ CHCl ₂ (30.0 g.)	CH ₃ MgI	[2,4,6-(CH ₃) ₃ C ₆ H ₂ CH=] ₂ (5.8 g.)	63
C₁₁H₁₅ClO₇			
Triacetyl-D-xylosyl chloride	C ₆ H ₅ MgX (<i>ca.</i> 10 equiv.)	CH ₃ (C ₆ H ₅) ₂ COH (100%, crude); after re- acetylation, triacetyl-D-xylopyranosyl- benzene (86.6%, crude: 25.0% α , 75.0% β)	109
Triacetyl-D-xylosyl chloride	4-CH ₃ C ₆ H ₄ MgX (<i>ca.</i> 10 equiv.)	CH ₃ (4-CH ₃ C ₆ H ₄) ₂ COH (100% crude); after re- acetylation, triacetyl-D-xylopyranosyl- toluene (82.3%, crude: 14.0% α , 86.0% β)	109

* Prepared by refluxing in xylene (three hours at 130°) the Grignard reagent from (+)- α -pinene hydrochloride; Rivière (188) concludes that the reagent so obtained is substantially pure bornylmagnesium chloride.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₁H₁₅Br			
CH ₃ (C ₂ H ₅)(C ₆ H ₅ CH ₂)CBr	C ₂ H ₅ MgBr (excess)	Mixture of sat'd and unsat'd h.c., probably CH ₃ (C ₂ H ₅)(C ₆ H ₅ CH ₂)CH + CH ₃ (C ₂ H ₅)C = CHC ₆ H ₅ ; C ₂ H ₄ ; C ₂ H ₆ ; MgBr ₂	223
C₁₁H₁₇Br			
C ₁₁ H ₁₇ Br*	CH ₃ MgI	C ₁₁ H ₁₇ CH ₃ [†]	157
C₁₂H₁₇Cl			
2,6-(CH ₃) ₂ -4- <i>i</i> -C ₃ H ₇ C ₆ H ₂ CH ₂ Cl	CH ₃ MgI	[2,6-(CH ₃) ₂ -4- <i>i</i> -C ₃ H ₇ C ₆ H ₂ CH ₂ —] ₂ (85%); 2,6-(CH ₃) ₂ -4- <i>i</i> -C ₃ H ₇ C ₆ H ₂ C ₂ H ₅ ("a little")	64
C₁₃H₉Cl			
9-Chlorofluorene	C ₂ H ₅ MgI	9-Ethylfluorene (65%); 9,9'-bifluorenyl (20%)	155
9-Chlorofluorene	<i>n</i> -C ₄ H ₉ MgBr	9,9'-Bifluorenyl (95%)	155
9-Chlorofluorene	<i>n</i> -C ₅ H ₁₁ MgBr	9,9'-Bifluorenyl (95%)	155
9-Chlorofluotene	C ₆ H ₅ MgBr	9,9'-Bifluorenyl (<i>ca.</i> quant.)	155
9-Chlorofluorene	(CH ₂) ₅ CHMgBr	9,9'-Bifluorenyl (93%) [‡] §	155
9-Chlorofluorene	(CH ₂) ₅ CHMgBr	9,9'-Bifluorenyl (70%); 9-cyclohexyl- fluorene (25%) [§] [†]	155

* The monobromo derivative obtained by treating 2-methyl-1,4,4a,5,6,7,8,8a-octahydronaphthalene with *N*-bromosuccinimide.

[†] A dimethyl derivative of 1,4,4a,5,6,7,8,8a-octahydronaphthalene.

[‡] Addition of chloride to ethereal Grignard reagent solution.

§ According to Miller and Bachman (155), the "normal" reaction is attributable to RMgX and the coupling reaction to R₂Mg. The Schlenk equilibrium is presumed to be relatively favorable to R₂Mg in ethyl ether solution and to RMgX in benzene.

[†] Addition of chloride to benzene-Grignard reagent solution.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₃H₉Cl₃ (4-ClC ₆ H ₄) ₂ CHCl (0.11 mole)	CH ₃ MgBr (0.12 mole)	(4-ClC ₆ H ₄) ₂ CHCH ₃ (95%)	92
C₁₃H₉Br 9-Bromofluorene	9-Phenanthryl-MgBr	9-(9-Fluorenyl)phenanthrene (50%)	9
9-Bromofluorene	(C ₆ H ₅) ₃ CMgBr	9-Triphenylmethylfluorene (99%)	8
C₁₃H₁₁Br (C ₆ H ₅) ₂ CHBr	CH ₃ MgBr	(C ₆ H ₅) ₂ CHCH ₃ (85%); [(C ₆ H ₅) ₂ CH —] ₂	212
(C ₆ H ₅) ₂ CHBr (5 g.)	C ₂ H ₅ MgBr	(C ₆ H ₅) ₂ CHC ₂ H ₅ (1.2 g., 30%); [(C ₆ H ₅) ₂ CH —] ₂	212
(C ₆ H ₅) ₂ CHBr (3.8 g.)	C ₂ H ₅ MgI	(C ₆ H ₅) ₂ CHC ₂ H ₅ (0.5 g., 15.7%); [(C ₆ H ₅) ₂ CH —] ₂ (1.9 g., 73%)	212
(C ₆ H ₅) ₂ CHBr	(C ₆ H ₅ SO ₂) ₂ C(MgBr) ₂	(C ₆ H ₅ SO ₂) ₂ CHCH(C ₆ H ₅) ₂	254
(C ₆ H ₅) ₂ CHBr	9-Anthryl-MgBr	9-Benzhydrylanthracene (10%)	11
(C ₆ H ₅) ₂ CHBr	9-Phenylanthryl-MgBr	9-Benzhydrylphenanthrene (72%)	9
(C ₆ H ₅) ₂ CHBr (27.8 g.)	(C ₆ H ₅) ₃ CMgBr (32.3 g. C ₁₉ H ₁₅ Br)	(C ₆ H ₅) ₃ CCH(C ₆ H ₅) ₂ (37 g.)	8
C₁₃H₁₉Cl 2,6-(CH ₃) ₂ -4- <i>t</i> -C ₄ H ₉ C ₆ H ₂ CH ₂ Cl	CH ₃ MgI	[2,6-(CH ₃) ₂ -4- <i>t</i> -C ₄ H ₉ C ₆ H ₂ CH ₂ —] ₂ (85%)	64
C₁₄H₉Br 9-Bromoanthracene	CH ₃ MgBr + FeCl ₃ (trace)	9-Methylanthracene (70%)	282
C₁₄H₁₀Cl (C ₆ H ₅ Cl ₂ C —) ₂ (0.7 g.)	CH ₃ MgCl (excess 2M)	(C ₆ H ₅ ClC =) ₂ (2 isomers, 0.2 g.)	67
C₁₄H₁₂Br₂ (C ₆ H ₅ CHBr —) ₂ (17 g.)	C ₆ H ₅ MgBr (5 g. Mg)	(C ₆ H ₅ CH =) ₂ (8 g.); (C ₆ H ₅ —) ₂ (7.8 g.)	128

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₁₄H₁₃ClO			
C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)CHCl	(C ₆ H ₅) ₃ CMgBr	C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)CHC(C ₆ H ₅) ₃ (70%)	8
C₁₄H₁₃Br			
C ₆ H ₅ (4-CH ₃ C ₆ H ₄)CHBr	(C ₆ H ₅) ₃ CMgBr	C ₆ H ₅ (4-CH ₃ C ₆ H ₄)CHC(C ₆ H ₅) ₃ (80%)	8
C₁₄H₁₉ClO₉			
Tetraäcetyl- α -D-glucosyl chloride	<i>i</i> -C ₃ H ₇ MgX (<i>ca.</i> 12 equiv.)	CH ₃ (<i>i</i> -C ₃ H ₇) ₂ COH (50.8%, crude); unidentified syrup mixture	109
Tetraäcetyl- α -D-glucosyl chloride	<i>n</i> -C ₄ H ₉ MgX (<i>ca.</i> 12 equiv.)	CH ₃ (<i>n</i> -C ₄ H ₉) ₂ COH (95.6%, crude); after reäcetylation, 1-tetraäcetyl-D-glucopyranosylbutane (59.4%, crude)	109
Tetraäcetyl- α -D-glucosyl chloride (0.0136 mole)	C ₆ H ₅ MgBr (0.165 mole C ₆ H ₅ Br)	CH ₃ (C ₆ H ₅) ₂ COH (100%, crude); after reäcetylation, tetraäcetyl-D-glucopyranosylbenzene (82.0%, crude; 28.4% α , 71.6% β)	109
Tetraäcetyl- α -D-glucosyl chloride	C ₆ H ₅ CH ₂ MgX (<i>ca.</i> 12 equiv.)	CH ₃ (C ₆ H ₅ CH ₂) ₂ COH (100%, crude); unidentified syrup mixture	109
Tetraäcetyl- α -D-glucosyl chloride	4-CH ₃ C ₆ H ₄ MgBr (<i>ca.</i> 12 equiv.)	CH ₃ (4-CH ₃ C ₆ H ₄) ₂ COH (98.5%, crude); after reäcetylation, 4-(tetraäcetyl-D-glucopyranosyl)toluene (75% crude; 26.6% α , 73.4% β)	109
Tetraäcetyl- α -D-glucosyl chloride	1-C ₁₀ H ₇ MgX (<i>ca.</i> 12 equiv.)	CH ₃ (1-C ₁₀ H ₇) ₂ COH (66%, crude); after reäcetylation, 1-tetraäcetyl-D-glucopyranosylnaphthalene (65.0%, crude; 33.3% α , 66.7% β)	109
Tetraäcetylfructosyl chloride (3 g.)	C ₂ H ₅ MgI (25 g. C ₂ H ₅ I)	C ₁₄ H ₉ ClO ₉ ·(C ₂ H ₅ MgI) ₂ (regenerating original chloride upon hydrolysis)	58

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₁₄H₁₉BrO₉			
Tetraäcetylglucosyl bromide	CH ₃ MgI (2 equiv.)	C ₁₄ H ₁₉ BrO ₉ ·(CH ₃ MgI) ₂ (regenerating original 56 bromide upon hydrolysis)	
Tetraäcetyl- α -D-glucosyl bromide (0.0122 mole)	C ₆ H ₅ MgBr (0.0911 mole) + 4-CH ₃ C ₆ H ₄ MgBr (0.0425 mole)	Tetraäcetyl-D-glucopyranosylbenzene (A) + 4-(tetraäcetyl-D-glucopyranosyl)-toluene (B) (3.38 g. total crude; 90% A, 10% B)	109
C₁₄H₂₁ClO			
4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ CH(CH ₃)-CH ₂ OCH ₂ Cl	RMgX*	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ CH(CH ₃)CH ₂ OCH ₂ R*	166
C₁₄H₂₇ClO			
1,1,3-Trimethyl-2-(γ -chloromethoxy- <i>n</i> -butyl)cyclohexane [†]	C ₂ H ₅ MgI	1,1,3-Trimethyl-2-(γ -propoxy- <i>n</i> -butyl)-cyclohexane ("poor yield")	115
1,1,3-Trimethyl-2-(γ -chloromethoxy- <i>n</i> -butyl)cyclohexane [†]	<i>i</i> -C ₃ H ₇ MgBr	1,1,3-Trimethyl-2-(γ -isobutoxy- <i>n</i> -butyl)cyclohexane ("poor yield")	115
C₁₅H₁₂Cl₂			
C ₆ H ₅ (C ₆ H ₅ CCl=CH)CHCl (30 g.)	C ₆ H ₅ MgBr (30 g. C ₆ H ₅ Br)	C ₆ H ₅ CCl=CH(C ₆ H ₅) ₂ CH (80-85%)	213
C₁₅H₁₃Cl			
(C ₆ H ₅) ₂ C=CHCH ₂ Cl	C ₆ H ₅ MgBr (5.3 ml. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ C=CHCH ₂ C ₆ H ₅	235
C₁₅H₁₅ClO₂			
(4-CH ₃ OC ₆ H ₄) ₂ CHCl	(C ₆ H ₅) ₃ CMgCl	(4-CH ₃ OC ₆ H ₄) ₂ CHC(C ₆ H ₅) ₃ (40%)	8

* R = CH₃, C₂H₅, *n*-C₃H₇, *n*-C₄H₉.[†]Chloromethyl ether of tetrahydroionol.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₁₅H₁₅Br			
(4-CH ₃ C ₆ H ₄) ₂ CHBr	(C ₆ H ₅) ₃ CMgBr	(4-CH ₃ C ₆ H ₄) ₂ CHC(C ₆ H ₅) ₃ (71%)	8
C₁₅H₁₅BrO₂			
(4-CH ₃ OC ₆ H ₄) ₂ CHBr	(C ₆ H ₅) ₃ CMgBr	(4-CH ₃ OC ₆ H ₄) ₂ CHC(C ₆ H ₅) ₃ (40%)	8
C₁₆H₁₅BrO₂			
4-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CO]C ₆ H ₄ Br (10 g.)	C ₆ H ₅ MgBr (0.5 g. C ₆ H ₅ Br) + Mg (1.0 g.)	{4-[2,4,6-(CH ₃) ₃ C ₆ H ₂ CO]C ₆ H ₄ —} ₂ (2.0 g.)*	61
C₁₆H₁₇Br			
CH ₃ (C ₆ H ₅ CH ₂) ₂ CBr (40 g.)	C ₂ H ₅ MgBr	[CH ₃ (C ₆ H ₅ CH ₂) ₂ C—] ₂ (0.5 g.); CH ₃ (C ₆ H ₅ CH ₂) ₂ CH; CH ₃ (C ₆ H ₅ CH ₂)C = CHC ₆ H ₅ (?); C ₂ H ₆ ; C ₂ H ₄	223
CH ₃ (C ₆ H ₅ CH ₂) ₂ CBr	C ₆ H ₅ CH ₂ MgCl (4 equiv.)	(C ₆ H ₅ CH ₂) ₃ CCH ₃ ; "olefin" (chief product)	223
C₁₆H₂₄Cl₂			
2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ CHCl ₂	CH ₃ Mgl	[2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ CHCl—] ₂ (2 isomers)	62
C₁₆H₂₅Cl			
2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ CH ₂ Cl	CH ₃ Mgl	[2,4,6-(<i>i</i> -C ₃ H ₇) ₃ C ₆ H ₂ CH ₂ —] ₂ (63%)	65
C₁₆H₃₃I			
<i>n</i> -C ₁₆ H ₃₃ I	CH ₃ Mgl	C ₁₇ H ₃₆ ; C ₁₆ H ₃₂ ; C ₂ H ₆ ; CH ₄	212
C₁₇H₁₃Br			
C ₆ H ₅ (1-C ₁₀ H ₇)CHBr	(C ₆ H ₅) ₃ CMgBr	C ₆ H ₅ (1-C ₁₀ H ₇)CHC(C ₆ H ₅) ₃ (72%)	8

* This reaction probably has more in common with the magnesium halide ketone reductions (*q.v.*, Chapter VI) than with the halide coupling reactions which it formally resembles.

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₇H₁₉Br			
C ₂ H ₅ (C ₆ H ₅ CH ₂) ₂ CBr	C ₆ H ₅ MgBr	Unsat'd hydrocarbon (chief product)	44
C₁₈H₂₀ClO₂N			
α-Chlorocodide (8 g.)	CH ₃ MgI (75 ml. 1M)	Desoxycodine-A (5.5 g.); gas (largely unsat'd); iodocodide (white form)	208
α-Chlorocodide (3 g.)	C ₂ H ₅ MgI	Desoxycodine-A (2.0 g., crude); iodocodide (white form, 0.1 g.)	208
β-Chlorocodide	Alk-MgX	No reaction	208
Iodocodide, white form (1.0 g.)	CH ₃ MgI (25 ml. 1M)	Desoxycodine-A (0.4 g.); recovered iodide (0.3 g.)	208
C₁₈H₂₁ClO₂			
(C ₂ H ₅ O) ₂ CH(C ₆ H ₅) ₂ CCl (7.6 g.)	C ₆ H ₅ MgBr (0.6 g. Mg)	(C ₆ H ₅) ₂ CHCO ₂ H (3.3 g.); (C ₆ H ₅) ₂ CH ₂ (2.8 g.)	193
C₁₉H₁₂ClBr₃			
(4-BrC ₆ H ₄) ₃ CCl	C ₆ H ₅ MgBr	(4-BrC ₆ H ₄) ₃ CC ₆ H ₅ (43-45%)	204
(4-BrC ₆ H ₄) ₃ CCl	C ₆ H ₅ CH ₂ MgCl	(4-BrC ₆ H ₄) ₃ CCH ₂ C ₆ H ₅ (quant.)	80
C₁₉H₁₂Cl₄			
2-ClC ₆ H ₄ (4-ClC ₆ H ₄) ₂ CCl	C ₆ H ₅ CH ₂ MgCl	2-ClC ₆ H ₄ (4-ClC ₆ H ₄) ₂ CCH ₂ C ₆ H ₅ (quant.)	80
(4-ClC ₆ H ₄) ₃ CCl	C ₆ H ₅ MgBr	(4-ClC ₆ H ₄) ₃ CC ₆ H ₅ (38-49%)	204
C₁₉H₁₃Cl			
9-Chloro-9-phenylfluorene (21 g.)	C ₆ H ₅ MgBr (15 ml. C ₆ H ₅ Br)	9,9-Diphenylfluorene (5.3 g., 23%); 9,9'-diphenyl-9,9'-bifluorenyl (4.8 g., 26%); gum	8,7,201

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₁₉H₁₃Cl (<i>cont.</i>)			
9-Chloro-9-phenylfluorene	C ₆ H ₅ CH ₂ MgCl	9-Phenyl-9-benzylfluorene	81
C₁₉H₁₃Br			
9-Bromo-9-phenylfluorene	(C ₆ H ₅) ₃ CMgBr	9,9'-Diphenyl-9,9'-bifluorenyl (98%); [(C ₆ H ₅) ₃ C —] ₂	8
C₁₉H₁₄Cl₂			
4-ClC ₆ H ₄ (C ₆ H ₅) ₂ CCl	C ₆ H ₅ MgBr	4-ClC ₆ H ₄ (C ₆ H ₅) ₃ C (10%); 4-ClC ₆ H ₄ (4-C ₆ H ₅ C ₆ H ₄)(C ₆ H ₅)CH (28%); C ₆ H ₅ (4-C ₆ H ₅ C ₆ H ₄) ₂ CH (9%)	203
4-ClC ₆ H ₄ (C ₆ H ₅) ₂ CCl	C ₆ H ₅ CH ₂ MgCl (3 equiv.)	4-ClC ₆ H ₄ (C ₆ H ₅) ₂ CCH ₂ C ₆ H ₅ (quant.)	80
C₁₉H₁₄BrCl			
4-ClC ₆ H ₄ (C ₆ H ₅) ₂ CBr	C ₆ H ₅ MgBr	4-ClC ₆ H ₄ (C ₆ H ₅) ₃ C (9%); 4-ClC ₆ H ₄ (4-C ₆ H ₅ C ₆ H ₄)(C ₆ H ₅)CH (27%); C ₆ H ₅ (4-C ₆ H ₅ C ₆ H ₄) ₂ CH (17%)	203
C₁₉H₁₅Cl			
(C ₆ H ₅) ₃ CCl	CH ₃ MgBr	(C ₆ H ₅) ₃ CCH ₃ (95%)	212
(C ₆ H ₅) ₃ CCl	CH ₃ MgI	(C ₆ H ₅) ₃ CCH ₃ (70%)	81,80
(C ₆ H ₅) ₃ CCl	C ₂ H ₅ MgBr	(C ₆ H ₅) ₃ CC ₂ H ₅	81,80
(C ₆ H ₅) ₃ CCl (27 g.)	C ₂ H ₅ MgI (33 g. C ₂ H ₅ I)	(C ₆ H ₅) ₃ CC ₂ H ₅ (20.0 g.); (C ₆ H ₅) ₃ CH (4.5 g.); [(C ₆ H ₅) ₃ CO —] ₂ (0.3 g.); C ₂ H ₄ (428 ml.)	81
(C ₆ H ₅) ₃ CCl (25 g.)	<i>n</i> -C ₃ H ₇ MgBr (20 g. C ₃ H ₇ Br)	(C ₆ H ₅) ₃ CH (5.3 g.); (C ₆ H ₅) ₃ C- <i>n</i> -C ₃ H ₇ ; C ₃ H ₆	81
(C ₆ H ₅) ₃ CCl (25 g.)	<i>i</i> -C ₃ H ₇ MgBr (18 g. C ₃ H ₇ Br)	(C ₆ H ₅) ₃ CH (7.0 g.); (C ₆ H ₅) ₃ C- <i>i</i> -C ₃ H ₇ (6.0 g.)	81
(C ₆ H ₅) ₃ CCl (10 g.)	H ₂ C = CHC≡CMgBr (slight excess)	(C ₆ H ₅) ₃ CC≡CCH = CH ₂ (7.5 g.)	34
(C ₆ H ₅) ₃ CCl	<i>i</i> -C ₅ H ₁₁ MgBr	(C ₆ H ₅) ₃ C- <i>i</i> -C ₅ H ₁₁	81

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₁₉H₁₅Cl (<i>cont.</i>)			
(C ₆ H ₅) ₃ CCl	C ₆ H ₅ MgBr	(C ₆ H ₅) ₄ C (0.5-5.0%); [(C ₆ H ₅) ₃ C —] ₂ (chiefly)	83,154
(C ₆ H ₅) ₃ CCl	C ₆ H ₅ MgBr	(C ₆ H ₅) ₄ C (5-10%); (C ₆ H ₅) ₃ CH; (C ₆ H ₅) ₃ COH; [(C ₆ H ₅) ₃ CO —] ₂	80
(C ₆ H ₅) ₃ CCl (20 g., 0.072 mole)	C ₆ H ₅ MgBr (0.25 mole)	(C ₆ H ₅) ₄ C (0.2 g., 0.63%); 4-C ₆ H ₅ C ₆ H ₄ (C ₆ H ₅) ₂ CH (10.9 g., 47.4%)	71
(C ₆ H ₅) ₃ CCl	C ₆ H ₅ MgBr	(C ₆ H ₅) ₄ C (21-29%); 4-C ₆ H ₅ C ₆ H ₄ (C ₆ H ₅) ₂ CH (13-35%); (C ₆ H ₅) ₃ CH (2-14%); C ₆ H ₅ (4-C ₆ H ₅ C ₆ H ₄) ₂ CH (2.5-3.5%); 4-C ₆ H ₅ C ₆ H ₄ (C ₆ H ₅) ₃ C (0.5-0.8%); (4-C ₆ H ₅ C ₆ H ₄) ₃ CH (trace)*	204
(C ₆ H ₅) ₃ CCl (20 g.)	C ₆ H ₅ MgI (50 g. C ₆ H ₅ I)	[(C ₆ H ₅) ₃ C —] ₂ ; (C ₆ H ₅ —) ₂	195
(C ₆ H ₅) ₃ CCl	4-ClC ₆ H ₄ CH ₂ MgCl	(C ₆ H ₅) ₃ CC ₆ H ₄ -4-Cl	154
(C ₆ H ₅) ₃ CCl (14 g.)	C ₆ H ₅ CH ₂ MgCl (1.3 equiv. C ₇ H ₇ Cl)	(C ₆ H ₅) ₃ CCH ₂ C ₆ H ₅ (14.5 g.)	80,154
C₁₉H₁₅Br			
(C ₆ H ₅) ₃ CBr	C ₆ H ₅ MgBr	(C ₆ H ₅) ₄ C ("a little"); [(C ₆ H ₅) ₃ C —] ₂ ("more")	57
(C ₆ H ₅) ₃ CBr	C ₆ H ₅ MgBr	(C ₆ H ₅) ₄ C (5.0-7.5%); 4-C ₆ H ₅ C ₆ H ₄ (C ₆ H ₅) ₂ CH (50-77%)	204
C ₆ H ₅ (4-C ₆ H ₅ C ₆ H ₄)CHBr	(C ₆ H ₅) ₃ CMgBr	C ₆ H ₅ (4-C ₆ H ₅ C ₆ H ₄)CHC(C ₆ H ₅) ₃ (70%)	8
C₁₉H₁₅I			
(C ₆ H ₅) ₃ CI	C ₆ H ₅ MgBr	(C ₆ H ₅) ₄ C; 4-C ₆ H ₅ C ₆ H ₄ (C ₆ H ₅) ₂ CH [†]	204

* The results of eight experiments are here summarized; other experiments under various conditions and in various solvents are described in the same article (204).

[†]The same products as for the corresponding bromide or chloride, but in lower yields.

TABLE XVI-I (Continued)

Halide	RMgX	Product(s)	Ref.
C₂₀H₁₇ClO			
4-CH ₃ OC ₆ H ₄ (C ₆ H ₅) ₂ CCl	CH ₃ MgI	4-CH ₃ OC ₆ H ₄ (C ₆ H ₅) ₂ CCH ₃	114
4-CH ₃ OC ₆ H ₄ (C ₆ H ₅) ₂ CCl (3.9 g.)	C ₆ H ₅ MgBr (3 equiv.)	(C ₆ H ₅) ₃ CC ₆ H ₄ -4-OCH ₃ (0.185 g., 4.5%)	82
C₂₀H₁₇BrO			
2-CH ₃ OC ₆ H ₄ (C ₆ H ₅) ₂ CBr (6.16 g.)	C ₆ H ₅ MgBr (3 equiv.)	2-CH ₃ OC ₆ H ₄ (C ₆ H ₅) ₃ C (2.67 g., 38%)	82
C₂₁H₁₅Cl			
(1-C ₁₀ H ₇) ₂ CHCl	C ₆ H ₅ MgI	[(1-C ₁₀ H ₇) ₂ CH —] ₂	197
(1-C ₁₀ H ₇) ₂ CHCl (3 g.)	1-C ₁₀ H ₇ MgBr (4 g. C ₁₀ H ₇ Br)	[(1-C ₁₀ H ₇) ₂ CH —] ₂ (1 g.)	197
C₂₁H₁₇Cl			
C ₆ H ₅ [(C ₆ H ₅) ₂ C=CH]CHCl (2.0 g.)	C ₆ H ₅ MgBr (1.2 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₂ C=CHCH(C ₆ H ₅) ₂ ; {C ₆ H ₅ [(C ₆ H ₅) ₂ C=CH]CH —} ₂ (trace)	213
C₂₁H₁₇Br			
(C ₆ H ₅) ₂ C=C(C ₆ H ₅)CH ₂ Br	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)CH ₂ C ₆ H ₅ ; (C ₆ H ₅) ₂ CHC(C ₆ H ₅)=CHC ₆ H ₅ ; [(C ₆ H ₅) ₂ C=C(C ₆ H ₅)CH ₂ —] ₂	14
C₂₁H₁₉ClO₂			
2,4-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₂ CCl (6.77 g.)	C ₆ H ₅ MgBr (3 equiv.)	2,4-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₃ C (3.2 g., 52.6%)	82
2,5-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₂ CCl (9.35 g.)	C ₆ H ₅ MgI (3 equiv.)	2,5-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₃ C (6.1 g., 58%)	82
2,5-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₂ CCl (6.77 g.)	1-C ₁₀ H ₇ MgBr (3 equiv.)	2,5-(CH ₃ O) ₂ C ₆ H ₃ (1-C ₁₀ H ₇)(C ₆ H ₅) ₂ C (3.53 g., 41%)	82
3,4-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₂ CCl (6.77 g.)	C ₆ H ₅ MgBr (3 equiv.)	3,4-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₃ C (2.34 g., 30%)	82

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₁H₁₉BrO₂			
2,5-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₂ CBr (7.66 g.)	C ₆ H ₅ MgBr (3 equiv.)	2,5-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₃ C (4.4 g., 58%)	82
2,5-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₂ CBr (7.66 g.)	C ₆ H ₅ MgI (3 equiv.)	2,5-(CH ₃ O) ₂ C ₆ H ₃ (C ₆ H ₅) ₃ C (1.28 g., 17%)	82
C₂₂H₁₉ClO₂			
2-Chloro-2,3,3-triphenyl-1,4-dioxane	CH ₃ MgI	No reaction	217
C₂₂H₂₁Cl			
(4-CH ₃ C ₆ H ₄) ₃ CCl	C ₆ H ₅ MgBr	(4-CH ₃ C ₆ H ₄) ₃ CC ₆ H ₅ (31-41%)	204
C₂₂H₂₁Br			
(C ₆ H ₅ CH ₂) ₃ CBr	C ₂ H ₅ MgBr (excess)	(C ₆ H ₅ CH ₂) ₂ C = CHC ₆ H ₅ ; [(C ₆ H ₅ CH ₂) ₃ C —] ₂ ; gas	223
(C ₆ H ₅ CH ₂) ₃ CBr	C ₆ H ₅ CH ₂ MgCl (excess)	(C ₆ H ₅ CH ₂) ₄ C (5%); (C ₆ H ₅ CH ₂) ₂ C = CHC ₆ H ₅ (chief product)	223
C₂₄H₁₇Br			
2,4,6-(C ₆ H ₅) ₃ C ₆ H ₂ Br	2,4,6-(C ₆ H ₅) ₃ C ₆ H ₂ MgBr	No [2,4,6-(C ₆ H ₅) ₃ C ₆ H ₂ —] ₂	127
C₂₄H₁₉ClO			
4-CH ₃ O-1-C ₁₀ H ₆ (C ₆ H ₅) ₂ CCl	CH ₃ MgI	4-CH ₃ O-1-C ₁₀ H ₆ (C ₆ H ₅) ₂ CCH ₃	114
C₂₅H₁₉Br			
(4-C ₆ H ₅ C ₆ H ₄) ₂ CHBr	(C ₆ H ₅) ₃ CMgBr	(4-C ₆ H ₅ C ₆ H ₄) ₂ CHC(C ₆ H ₅) ₃ (90%)	8

TABLE XVI-I (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂₆H₂₀Cl₂			
[(C ₆ H ₅) ₂ CCl —] ₂	C ₆ H ₅ MgX*	[(C ₆ H ₅) ₂ C =] ₂ ; 4-C ₆ H ₅ C ₆ H ₄ (C ₆ H ₅)C = C(C ₆ H ₅) ₂	162
[(C ₆ H ₅) ₂ CCl —] ₂	RMgX [†]	[(C ₆ H ₅) ₂ C =] ₂	198
C₂₆H₃₅ClO₁₇			
Heptaäcetyllactosyl chloride	C ₆ H ₅ MgX (<i>ca.</i> 18 equiv.)	CH ₃ (C ₆ H ₅) ₂ COH (95.4%, crude); after re- äcetylation, heptaäcetyllactosylbenzene (69.4%, crude: 41.0% α, 59.0% β)	109
C₂₆H₃₅BrO₁₇			
Heptaäcetyllactosyl bromide (5 g.)	CH ₃ MgI (25 g. CH ₃ I)	C ₂₆ H ₃₅ BrO ₁₇ · 2CH ₃ MgI (regenerating original bromide upon hydrolysis)	58
C₂₇H₄₇ClO			
5-Chloro-3(β),6(β)-cholestanediol	CH ₃ MgI	5(α)-Methyl-3(β),6(β)-cholestanediol	274,275

* X = Br, I.

[†] RMgX = C₂H₅MgBt, C₆H₅MgBr, C₆H₅MgI.

REFERENCES FOR TABLE XVI-I

- (1) Akabori and Saito, *Ber.*, 63B, 2245-8 (1930).
- (2) Allen and Henze, *J. Am. Chem. Soc.*, 61, 1790-4 (1939).
- (3) Alles, Icke, and Feigen, *J. Am. Chem. Soc.*, 64, 2031-5 (1942).
- (4) Godchot and Cauquil, *Compt. rend.*, 186, 955-7 (1928).
- (5) André, *Ann. chim.*, [8], 29, 540-96 (1913).
- (6) Anzilotti and Vogt, *J. Am. Chem. Soc.*, 61, 572-3 (1939).
- (7) Bachmann, *J. Am. Chem. Soc.*, 52, 3287-90 (1930).
- (8) Bachmann, *J. Am. Chem. Soc.*, 55, 2135-9 (1933).
- (9) Bachmann, *J. Am. Chem. Soc.*, 56, 1363-7 (1934).
- (10) Bachmann and Cockerill, *J. Am. Chem. Soc.*, 55, 2932-4 (1933).
- (11) Bachmann and Kloetzel, *J. Org. Chem.*, 3, 55-61 (1938).
- (12) Bannerot and Bonner, *J. Am. Chem. Soc.*, 56, 1563-5 (1934).
- (13) Bergmann and Bergmann, *J. Am. Chem. Soc.*, 59, 1443-50 (1937).
- (14) Bergmann and Weiss, *Ber.*, 64B, 1485-93 (1931).
- (15) Berlande, *Compt. rend.*, 212, 437-9 (1941); *Chem. Abstr.*, 37, 2720 (1943).
- (16) Berlande, *Compt. rend.*, 213, 484-6 (1941); *Chem. Abstr.*, 37, 2720 (1943).
- (17) Bert, *Compt. rend.*, 180, 1504-6 (1925).
- (18) Bert, *Compt. rend.*, 186, 373-5 (1928).
- (19) Bert, *Compt. rend.*, 186, 587-8 (1928).
- (20) Binaghi, *Gazz. chim. ital.*, 52, 11, 132-8 (1922); *Chem. Zentr.*, 1923, 1, 1435; *Chem. Abstr.*, 17, 1425 (1923).
- (21) Binaghi, *Gazz. chim. ital.*, 53, 879-87 (1923); *Chem. Zentr.*, 1924, 11, 2356; *Chem. Abstr.*, 18, 1488 (1924).
- (22) Binaghi, *Gazz. chim. ital.*, 57, 669-75 (1927); *Chem. Zentr.*, 1928, 1, 908.
- (23) Bogert and Davidson, *J. Am. Chem. Soc.*, 56, 185-90 (1934).
- (24) Bordwell, Suter, and Webber, *J. Am. Chem. Soc.*, 67, 827-32 (1945).
- (25) Bourguet, *Compt. rend.*, 177, 688-90 (1923).
- (26) Boyle, McKenzie, and Mitchell, *Ber.*, 70B, 2153-60 (1937).
- (27) Brooks and Humphrey, *J. Am. Chem. Soc.*, 40, 822-56 (1918).
- (28) Bruylants, *Bull. acad. roy. Belg.*, 1908, 1011-84; *Chem. Zentr.*, 1909, 1, 1859.
- (29) Brückner, *Österr. Chem.-Ztg.*, 41, 363 (1938); *Chem. Zentr.*, 1939, 1, 918.
- (30) Buess, Karabinos, Kunz, and Gibbons, *Natl. Advisory Comm. Aeronaut., Tech. Note*, No. 1021, 8 pp. (1946); *Chem. Abstr.*, 41, 4113 (1947).
- (31) Bygdén, *Ber.*, 45, 3479-83 (1912).
- (32) Calingaert, Soroos, Hnizda, and Shapiro, *J. Am. Chem. Soc.*, 66, 1389-94 (1944).
- (33) Carothers, U. S. Patent 2,072,867, March 9, 1937; *Chem. Abstr.*, 31, P3335 (1937).
- (34) Carothers and Berchet, *J. Am. Chem. Soc.*, 55, 1094-6 (1933).
- (35) Carothers and Berchet, *J. Am. Chem. Soc.*, 55, 2813-7 (1933).
- (36) Christ and Summerbell, *J. Am. Chem. Soc.*, 55, 4547 (1933).
- (37) Clément and Savard, *Compt. rend.*, 204, 1742-3 (1937); *Chem. Abstr.*, 31, 7044 (1937).
- (38) Cleveland, *J. Chem. Phys.*, 11, 1-6 (1943).
- (39) Cottle and Hollyday, *J. Org. Chem.*, 12, 510-6 (1947).
- (40) Cottle, Jeltsch, Stoudt, and Walters, *J. Org. Chem.*, 11, 286-91 (1946).
- (41) Cottle and Powell, *J. Am. Chem. Soc.*, 58, 2267-72 (1936).
- (42) Crane, Boord, and Henne, *J. Am. Chem. Soc.*, 67, 1237-9 (1945).
- (43) Danehy, Killian, and Nieuwland, *J. Am. Chem. Soc.*, 58, 611-2 (1936).
- (44) Davies and Kipping, *J. Chem. Soc.*, 99, 296-301 (1911).
- (45) Deschamps, *J. Am. Chem. Soc.*, 42, 2670-3 (1920).
- (46) Dilthey and Hurtig, *Ber.*, 67B, 495-6, 2004-7 (1934).

- (47) Dionneau, *Ann. Chim.*, [9], 3, 194-268 (1915).
- (48) Dubinin, *J. Gen. Chem.* (U.S.S.R.), 7, 2183-7 (1937); *Chem. Abstr.*, 32, 516 (1938).
- (49) Dupont, *Ann. chim.*, [8], 30, 485-587 (1913).
- (50) Durand and Waï-Hsun, *Compt. rend.*, 191, 1460-3 (1930).
- (51) Dykstra, Lewis, and Boord, *J. Am. Chem. Soc.*, 52, 3396-404 (1930).
- (52) Edgar, Calingaert, and Marker, *J. Am. Chem. Soc.*, 51, 1483-91 (1929).
- (53) Elderfield, Craig, Lauer, Arnold, Gensler, Head, Bembry, Mighton, Tinker, Galbreath, Holley, Goldman, Maynard, and Picus, *J. Am. Chem. Soc.*, 68, 1516-23 (1943).
- (54) Ellingboe and Fuson, *J. Am. Chem. Soc.*, 55, 2960-6 (1933).
- (55) Ferrario and Fagetti, *Gazz. chim. ital.*, 38, 11, 630-4 (1908); *Chem. Zentr.*, 1909, 1, 436.
- (56) Fischer and Hess, *Ber.*, 45, 912-5 (1912).
- (57) Freund, *Ber.*, 39, 2237-8 (1906).
- (58) Fröschl, Zellner, and Zak., *Monatsh.*, 55, 25-46 (1930).
- (59) Fuson, *J. Am. Chem. Soc.*, 48, 830-6 (1926).
- (60) Fuson, *J. Am. Chem. Soc.*, 48, 2681-9 (1926).
- (61) Fuson and Armstrong, *J. Am. Chem. Soc.*, 63, 2650-2 (1941).
- (62) Fuson, Chadwick, and Ward, *J. Am. Chem. Soc.*, 68, 389-93 (1946).
- (63) Fuson, Denton, and Best, *J. Org. Chem.*, 8, 64-72 (1943).
- (64) Fuson, Denton, and Kneisley, *J. Am. Chem. Soc.*, 63, 2652-3 (1941).
- (65) Fuson, Kneisley, Rabjohn, and Ward, *J. Am. Chem. Soc.*, 68, 533 (1946).
- (66) Fuson and Porter, *J. Am. Chem. Soc.*, 70, 895-7 (1948).
- (67) Fuson and Ross, *J. Am. Chem. Soc.*, 55, 720-3 (1933).
- (68) Fuson, Speck, and Hatchard, *J. Org. Chem.*, 10, 55-61 (1945).
- (69) Gauthier, *Ann. chim.*, [11], 20, 581-659 (1945).
- (70) Geissman and Mallatt, *J. Am. Chem. Soc.*, 61, 1788-9 (1939).
- (71) Gilman and Jones, *J. Am. Chem. Soc.*, 51, 2840-3 (1929).
- (72) Gilman and Kirby, *J. Am. Chem. Soc.*, 54, 345-55 (1932).
- (73) Gilman and Van Ess, *J. Am. Chem. Soc.*, 61, 1365-71 (1939).
- (74) Godchot and Bedos, *Compt. rend.*, 178, 1184-6 (1924).
- (75) Godchot and Bedos, *Bull. soc. chim.*, [4], 37, 1451-66 (1925).
- (76) Godchot and Bedos, *Bull. soc. chim.*, [4], 37, 1637-51 (1925).
- (77) Godchot and Cauquil, *Compt. rend.*, 186, 375-7 (1928).
- (78) Golse, *Ann. chim.*, [12], 3, 527-69 (1948).
- (79) Golumbic and Cottle, *J. Am. Chem. Soc.*, 61, 996-1000 (1939).
- (80) Gomberg and Cone, *Ber.*, 39, 1461-70 (1906).
- (81) Gomberg and Cone, *Ber.*, 39, 2957-70 (1906).
- (82) Gomberg and Forrester, *J. Am. Chem. Soc.*, 47, 2373-91 (1925).
- (83) Gomberg and Kamm, *J. Am. Chem. Soc.*, 39, 2009-15 (1917).
- (84) Grédy, *Bull. soc. chim.*, [5], 3, 1093-101 (1936).
- (85) Grignard, *Compt. rend.*, 138, 1048-50 (1904); *J. Chem. Soc.*, 86, 1, 494 (1904).
- (86) Grignard, *Compt. rend.*, 141, 44-6 (1905); *J. Chem. Soc.*, 88, 1, 593 (1905).
- (87) Grignard, *Ann. chim.*, [8], 10, 23-40 (1905).
- (88) Grignard and Lepayre, *Bull. soc. chim.*, [4], 43, 141-2 (1928).
- (89) Grignard and Lepayre, *Compt. rend.*, 192, 250-3 (1931); *Chem. Abstr.*, 25, 2421 (1931).
- (90) Grignard, Lepayre, and Tchéoufaki, *Compt. rend.*, 187, 517-20 (1928).
- (91) Grignard and Tchéoufaki, *Bull. soc. chim.*, [4], 43, 42-3 (1928).
- (92) Grummit, Buck, and Becker, *J. Am. Chem. Soc.*, 67, 2265-6 (1945).
- (93) Guillemonat, *Ann. chim.*, [11], 11, 143-211 (1939).
- (94) Hamonet, *Compt. rend.*, 138, 813-4 (1904); *J. Chem. Soc.*, 86, 1, 401 (1904); *Chem. Zentr.*, 1904, 1, 1195.

- (95) Hamonet, *Compt. rend.*, 138, 975-7 (1904); *J. Chem. Soc.*, 86, I, 467 (1904); *Chem. Zentr.*, 1904, I, 1400.
- (96) Hamonet, *Compt. rend.*, 138, 1609-12 (1904); *J. Chem. Soc.*, 86, I, 705 (1904).
- (97) Hamonet, *Bull. soc. chim.*, [3], 33, 528-9 (1905).
- (98) Henne, Chanan, and Turk, *J. Am. Chem. Soc.*, 63, 3474-6 (1941).
- (99) Henne and Whaley, *J. Am. Chem. Soc.*, 64, 1157-9 (1942).
- (100) Henry, *Compt. rend.*, 144, 308-13 (1907); *Chem. Zentr.*, 1907, I, 1102.
- (101) Henry, *Rec. trav. chim.*, 26, 106-15 (1907).
- (102) Henry, *Bull. acad. roy. Belg., Classe sci.*, 1907, 162-89; *Chem. Zentr.*, 1907, II, 445.
- (103) Hershberg, *Helv. Chim. Acta*, 17, 351-8 (1934).
- (104) Hill, Short, and Stromberg, *J. Chem. Soc.*, 1937, 937-41.
- (105) Hoshino, *Abstr. Japan. Chem. Lit.*, 6, 390-1 (1932); *Chem. Abstr.*, 27, 291 (1933).
- (106) Houben, *Ber.*, 36, 3083-6 (1903).
- (107) Houben and Führer, *Ber.*, 40, 4990-5000 (1907).
- (108) Hurd and Bollman, *J. Am. Chem. Soc.*, 56, 447-9 (1934).
- (109) Hurd and Bonner, *J. Am. Chem. Soc.*, 67, 1972-7 (1945).
- (110) Huston and Bostwick, *J. Org. Chem.*, 13, 331-8 (1948).
- (111) Huston, Jackson, and Spero, *J. Am. Chem. Soc.*, 63, 1459-60 (1941).
- (112) Hyman and Wagner, *J. Am. Chem. Soc.*, 52, 4345-9 (1930).
- (113) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 38, 920-1 (1906); *Bull. soc. chim.*, [4], 4, 1558 (1908).
- (114) Julian and Gist, *J. Am. Chem. Soc.*, 57, 2030-2 (1935).
- (115) Kandel, *Ann. chim.*, [11], 11, 73-142 (1939).
- (116) Karrer, Salomon, Morf, and Walker, *Helv. Chim. Acta*, 15, 878-89 (1932).
- (117) Kazanskiĭ, Liberman, Plate, Rosengart, and Tarasova, *J. Gen. Chem. (U.S.S.R.)*, 17, 1503-10 (1947); *Chem. Abstr.*, 42, 2225 (1948).
- (118) Kharasch, Engelmann, and Urry, *J. Am. Chem. Soc.*, 66, 365-7 (1944).
- (119) Kharasch and Fuchs, *J. Org. Chem.*, 9, 359-72 (1944).
- (120) Kharasch and Fuchs, U. S. Patent 2,409,287, Oct. 15, 1946; *Chem. Abstr.*, 41, P990 (1947).
- (121) Kharasch, Lambert, and Urry, *J. Org. Chem.*, 10, 298-306 (1945).
- (122) Kinney and Spliethoff, *J. Org. Chem.*, 14, 71-8 (1949).
- (123) Kirmann, *Bull. soc. chim.*, [4], 39, 988-91 (1926).
- (124) Kirmann, *Bull. soc. chim.*, [4], 41, 316-23 (1927).
- (125) Kirmann and Jacob, *Bull. soc. chim.*, [5], 7, 586-93 (1940).
- (126) Kirmann, Pacaud, and Dosque, *Bull. soc. chim.*, [5], 1, 860-71 (1934).
- (127) Kohler and Blanchard, *J. Am. Chem. Soc.*, 57, 367-71 (1935).
- (128) Kohler and Johnstin, *Am. Chem. J.*, 33, 35-45 (1905).
- (129) Korschak, *J. Gen. Chem. (U.S.S.R.)*, 9, 1153-4 (1939); *Chem. Zentr.*, 1940, I, 196; *Chem. Abstr.*, 34, 1303 (1940).
- (130) Kozacik and Reid, *J. Am. Chem. Soc.*, 60, 2436-8 (1938).
- (131) Krizewsky and Turner, *J. Chem. Soc.*, 115, 559-61 (1919).
- (132) Kuznetsov, *J. Gen. Chem. (U.S.S.R.)*, 16, 187-91 (1946); *Chem. Abstr.*, 41, 443 (1947).
- (133) Leendertse, *Rec. trav. chim.*, 53, 715-24 (1934).
- (134) Lespieau, *Ann. chim.*, [9], 2, 280-92 (1914).
- (135) Lespieau, *Compt. rend.*, 170, 1584-5 (1920).
- (136) Lespieau, *Bull. soc. chim.*, [4], 29, 528-35 (1921).
- (137) Lespieau, *Bull. soc. chim.*, [4], 43, 1189-93 (1928).
- (138) Lespieau, *Compt. rend.*, 187, 605-7 (1928); *Chem. Abstr.*, 23, 817 (1929).
- (139) Lespieau, *Compt. rend.*, 188, 502-3 (1929); *Brit. Chem. Abstr.*, 1929A, 421.
- (140) Lespieau, *Compt. rend.*, 188, 998-1000 (1929).

- (141) Lespieau and Bresch, *Compt. rend.*, 156, 710-2 (1913); *Chem. Abstr.*, 7, 2213 (1913).
- (142) Lespieau and Deluchat, *Compt. rend.*, 183, 889-91 (1926); *Chem. Zentr.*, 1927,1, 260.
- (143) Lespieau and Dupont, *Bull. soc. chim.*, [4], 1, 4 (1907).
- (144) Lespieau and Guillemonat, *Compt. rend.*, 195, 245-7 (1932).
- (145) Levina, Faĩnzil'berg, and Shusherina, *J. Gen. Chem. (U.S.S.R.)*, 18, 1775-80 (1948); *Chem. Abstr.*, 43, 3344 (1949).
- (146) Levina, Skvarchenko, Kagan, and Treshchova, *J. Gen. Chem. (U.S.S.R.)*, 18, 62-8 (1949); *Chem. Abstr.*, 43, 6152 (1949).
- (147) Levy and Cope, *J. Am. Chem. Soc.*, 66, 1684-8 (1944).
- (148) Magrane and Cottle, *J. Am. Chem. Soc.*, 64, 484-7 (1942).
- (149) Majima and Hoshino, *Ber.*, 58B, 2042-6 (1925).
- (150) Marker and Oakwood, *J. Am. Chem. Soc.*, 60, 2598 (1938).
- (151) Mason, *J. Am. Chem. Soc.*, 67, 1538-40 (1945).
- (152) McKenzie, Drew, and Martin, *J. Chem. Soc.*, 107, 26-32 (1915).
- (153) McKinley, U. S. Patent 2,415,599, Feb. 11, 1947; *Chem. Abstr.*, 41, P3123 (1947).
- (154) Meyer, *J. prakt. Chem.*, [2], 82, 521-38 (1910).
- (155) Miller and Bachman, *J. Am. Chem. Soc.*, 57, 766-71 (1935).
- (156) Mousseron, *Bull. soc. chim.*, [5], 12, 73 (1945); *Chem. Abstr.*, 40, 845 (1946).
- (157) Mousseron and Manon, *Compt. rend.*, 227, 533-4 (1948); *Chem. Abstr.*, 43, 2173 (1949).
- (158) Mousseron and Winternitz, *Bull. soc. chim.*, [5], 12, 71-2 (1945).
- (159) Mousseron and Winternitz, *Bull. soc. chim.*, [5], 13, 604-10 (1946).
- (160) Mulliken, Wakeman and Gerry, *J. Am. Chem. Soc.*, 57, 1605-7 (1935).
- (161) Normant, *Ind. parfum.*, 3, 136-8 (1948); *Chem. Abstr.*, 42, 7237 (1948).
- (162) Norris, Thomas, and Brown, *Ber.*, 43, 2940-59 (1910).
- (163) Oddo and Binaghi, *Gazz. chim. ital.*, 51,11, 330-7 (1921); *Chem. Zentr.*, 1922,1, 1025; *Chem. Abstr.*, 16, 1392 (1922).
- (164) Oroshnik, *J. Am. Chem. Soc.*, 67, 1627-8 (1945).
- (165) Ozanne and Marvel, *J. Am. Chem. Soc.*, 52, 5267-72 (1930).
- (166) Palfray, Sabetay, and Reynaud, *Compt. rend.*, 224, 939-41 (1947); *Chem. Abstr.*, 41, 4785 (1947).
- (167) Paul, *Compt. rend.*, 198, 1246-8 (1934).
- (168) Paul, *Compt. rend.*, 218, 122-4 (1944); *Chem. Abstr.*, 40, 2447 (1946).
- (169) Paul and Riobé, *Compt. rend.*, 224, 474-6 (1947); *Chem. Abstr.*, 41, 4771 (1947).
- (170) Plate, Sterligov, and Bazhulin, *J. Gen. Chem. (U.S.S.R.)*, 14, 955-9 (1944); *Chem. Abstr.*, 39, 4594 (1945).
- (171) Platé, *Compt. rend. acad. sci. U.R.S.S., Classe sci. chim.*, 24, 257-62 (1939); *Chem. Abstr.*, 34, 994 (1940).
- (172) Prévost, *Compt. rend.*, 187, 946-8 (1928).
- (173) Prévost, *Bull. soc. chim.*, [4], 49, 1372-81 (1931).
- (174) Prévost and Daujat, *Bull. soc. chim.*, [4], 47, 588-94 (1930).
- (175) Pudovic and Arbuzov, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1948, 246-9; *Chem. Abstr.*, 42, 4973 (1948).
- (176) Quelet, *Compt. rend.*, 182, 1283-5 (1926).
- (177) Quelet, *Compt. rend.*, 184, 888-90 (1927).
- (178) Quelet, *Bull. soc. chim.*, [4], 45, 75-97 (1929).
- (179) Quelet and Golse, *Compt. rend.*, 224, 661-3 (1947); *Chem. Abstr.*, 41, 4779 (1947).
- (180) Quelet and Golse, *Bull. soc. chim.*, [5], 14, 313-6 (1947).

- (181) Quelet and Pineau, *Compt. rend.*, 222, 1237-8 (1946); *Chem. Abstr.*, 40, 5397 (1946).
- (182) Rebek and Mandrino, *Österr. Chem.-Ztg.*, 41, 49-52 (1938); *Chem. Zentr.*, 1938,II, 1204; *Chem. Abstr.*, 32, 3755 (1938).
- (183) Rebek and Mandrino, *Österr. Chem.-Ztg.*, 41, 363-4 (1939); *Chem. Zentr.*, 1939,I, 919.
- (184) Reformatsky, Grischkewitsch-Frochimosky, and Semenzow, *Ber.*, 44, 1885-6 (1911).
- (185) Regier and Blue, *J. Org. Chem.*, 14, 505-8 (1949).
- (186) Reyckler, *Bull. soc. chim.*, [3], 35, 737-40 (1906).
- (187) Ribas, *Anales soc. españ. fis. quim.*, 26, 122-32 (1928); *Chem. Zentr.*, 1928,II, 40.
- (188) Rivière, *Ann. chim.*, [12], 1, 157-231 (1946).
- (189) Ruzicka, Ehmann, and Morgell, *Helv. Chim. Acta*, 16, 314-26 (1933).
- (190) Korshak and Kozarenko, *Doklady Akad. Nauk S.S.S.R.*, 76, 685-7 (1951); *Chem. Abstr.*, 45, 8435 (1951).
- (191) Sanna, *Rend. seminar. facoltà sci. univ. Cagliari*, 5, 76-81 (1935); *Chem. Zentr.*, 1937,II, 2345; *Chem. Abstr.*, 33, 5833 (1939).
- (192) Savard and Hösöğüt, *Rev. faculté sci. univ. Istanbul*, [N.S.], 3, 164-73 (1938); *Chem. Abstr.*, 32, 5795 (1938).
- (193) Scheibler and Schmidt, *Ber.*, 67B, 1514-8 (1934).
- (194) Schmerling and Ipatieff, U. S. Patent 2,404,927, July 30, 1946; *Chem. Abstr.*, 40, P6494 (1946).
- (195) Schmidlin, *Ber.*, 43, 1137-44 (1910).
- (196) Grignard, Lepayre, and Tchéoufaki, *Bull. soc. chim.*, [4], 43, 931-2 (1928).
- (197) Schmidlin and Massini, *Ber.*, 42, 2377-92 (1909).
- (198) Schmidlin and von Escher, *Ber.*, 43, 1153-61 (1910).
- (199) Schmidt and Hartmann, *Ber.*, 74B, 1325-32 (1941).
- (200) Schmidt, Schoeller, and Eberlein, *Ber.*, 74B, 1313-24 (1941).
- (201) Schmidt-Nickels, *Ber.*, 62B, 917-9 (1929).
- (202) Schmitt and Boord, *J. Am. Chem. Soc.*, 54, 751-61 (1932).
- (203) Schoepfle and Trepp, *J. Am. Chem. Soc.*, 54, 4059-65 (1932).
- (204) Schoepfle and Trepp, *J. Am. Chem. Soc.*, 58, 791-4 (1936).
- (205) Shoemaker and Boord, *J. Am. Chem. Soc.*, 53, 1505-12 (1931).
- (206) Shoesmith and Connor, *J. Chem. Soc.*, 1927, 1768-72.
- (207) Sirks, *Rec. trav. chim.*, 65, 850-8 (1946).
- (208) Small and Cohen, *J. Am. Chem. Soc.*, 53, 2214-26 (1931).
- (209) Smith and Perry, *J. Am. Chem. Soc.*, 61, 1411-2 (1939).
- (210) Soday and Boord, *J. Am. Chem. Soc.*, 55, 3293-302 (1933).
- (211) Grignard, *Bull. soc. chim.*, [3], 33, 918-9 (1905).
- (212) Späth, *Monatsh.*, 34, 1965-2014 (1913).
- (213) Straus and Ehrenstein, *Ann.*, 442, 93-118 (1925).
- (214) Summerbell and Bauer, *J. Am. Chem. Soc.*, 57, 2364-8 (1935).
- (215) Summerbell and Bauer, *J. Am. Chem. Soc.*, 58, 759-61 (1936).
- (216) Summerbell and Umhoefer, *J. Am. Chem. Soc.*, 61, 3016 (1939).
- (217) Summerbell, Umhoeffer, and Lappin, *J. Am. Chem. Soc.*, 69, 1352-4 (1947).
- (218) Swallen and Boord, *J. Am. Chem. Soc.*, 52, 651-60 (1930).
- (219) Tchéoufaki, *Contrib. Inst. Chem. Natl. Acad. Peiping*, 1, 127-52 (1934); *Chem. Zentr.*, 1937,II, 2982.
- (220) Tiffeneau, *Bull. soc. chim.*, [3], 29, 1156-8 (1903).
- (221) Tiffeneau, *Compt. rend.*, 139, 481-2 (1904); *Chem. Zentr.*, 1904,II, 1038.
- (222) Tiffeneau, Ditz, and Tchoubar, *Compt. rend.*, 198, 1039-41 (1934); *Chem. Abstr.*, 28, 3720 (1934).
- (223) Trotman, *J. Chem. Soc.*, 127, 88-95 (1925).
- (224) Vavon and Mitchovitch, *Compt. rend.*, 186, 702-5 (1928).

- (225) Vavon and Mottez, *Compt. rend.*, 218, 557-9 (1944); *Chem. Abstr.*, 39, 2739 (1945).
- (226) Velick and English, *J. Biol. Chem.*, 160, 473-80 (1945).
- (227) von Braun, Deutsch, and Schmatloch, *Ber.*, 45, 1246-63 (1912).
- (228) von Braun, Kamp, and Kopp, *Ber.*, 70B, 1750-60 (1937).
- (229) von Braun and Kühn, *Ber.*, 60B, 2551-7 (1927).
- (230) von Braun and Reitz-Kopp, *Ber.*, 74B, 1105-10 (1941).
- (231) Waterman and de Kok, *Rec. trav. chim.*, 52, 251-6 (1933).
- (232) Waterman and de Kok, *Rec. trav. chim.*, 52, 298-302 (1933).
- (233) Waterman and de Kok, *Rec. trav. chim.*, 53, 725-9 (1934).
- (234) Waterman and de Kok, *Rec. trav. chim.*, 53, 1133-8 (1934).
- (235) Weizmann and Bergmann, *J. Chem. Soc.*, 1936, 401-2.
- (236) Whitmore and Fleming, *J. Am. Chem. Soc.*, 55, 3803-6 (1933).
- (237) Whitmore, Herr, Clarke, Rowland, and Schiessler, *J. Am. Chem. Soc.*, 67, 2059-61 (1945).
- (238) Whitmore and Homeyer, *J. Am. Chem. Soc.*, 55, 4555-9 (1933).
- (239) Whitmore and Sloat, *J. Am. Chem. Soc.*, 64, 2968-70 (1942).
- (240) Whitmore, Stehman, and Herndon, *J. Am. Chem. Soc.*, 55, 3807-9 (1933).
- (241) Wibaut, Hoog, Langedijk, Overhoff, and Smittenberg, *Rec. trav. chim.*, 58, 329-77 (1939).
- (242) Wilkinson, *J. Chem. Soc.*, 1931, 3057-62.
- (243) Wilson, Roberts, and Young, *J. Am. Chem. Soc.*, 71, 2019-20 (1949).
- (244) Witman, U. S. Patent 2,290,401, July 21, 1943; *Chem. Abstr.*, 37, P388 (1943).
- (245) Young, Roberts, and Wax, *J. Am. Chem. Soc.*, 67, 841-3 (1945).
- (246) Yur'ev, Voronkov, Gragerov, and Kondrat'eva, *J. Gen. Chem. (U.S.S.R.)*, 18, 1804-10 (1948); *Chem. Abstr.*, 43, 3818 (1949).
- (247) Godchot, Bedos, and Cauquil, *Bull. soc. chim.*, [4], 43, 521-2 (1928).
- (248) Zakharova, *J. Gen. Chem. (U.S.S.R.)*, 17, 1277-85 (1947); *Chem. Abstr.*, 42, 3722 (1948).
- (249) Zeltner and Tarassoff, *Ber.*, 43, 941-5 (1910).
- (250) Hess, *Ber.*, 46, 3125-9 (1913).
- (251) Hoshino and Shimodaira, *Ann.*, 520, 19-30 (1935).
- (252) Mousseron and Winternitz, *Compt. rend.*, 221, 701-3 (1945); *Chem. Abstr.*, 41, 101 (1947).
- (253) Stahl and Cottle, *J. Am. Chem. Soc.*, 65, 1782-3 (1943).
- (254) Lutz, Allison, Ashburn, Bailey, Clark, Codington, Deinet, Freek, Jordan, Leake, Martin, Nicodemus, Rowlett, Shearer, Smith, and Wilson, *J. Org. Chem.*, 12, 617-703 (1947).
- (255) Levina and Egorova, *J. Gen. Chem. (U.S.S.R.)*, 16, 821-4 (1946); *Chem. Abstr.*, 41, 1596 (1947).
- (256) Johnson, *J. Chem. Soc.*, 1946, 1009-14.
- (257) Mousseron, Winternitz, and Combes, *Compt. rend.*, 223, 909-11 (1946); *Chem. Abstr.*, 41, 1622 (1947).
- (258) Sontag, *Ann. chim.*, [11], 1, 359-438 (1934).
- (259) Dice, Watkins, and Schuman, *J. Am. Chem. Soc.*, 72, 1738-40 (1950).
- (260) Schorigin, Issaguljanz, Gussewa, Ossipowa, and Poljakowa, *Ber.*, 64B, 2584-90 (1931).
- (261) Glattfeld and Cameron, *J. Am. Chem. Soc.*, 49, 1043-8 (1927).
- (262) Bergmann and Blum-Bergmann, *J. Am. Chem. Soc.*, 58, 1678-81 (1936).
- (263) Malm and Summers, *J. Am. Chem. Soc.*, 73, 362-3 (1951).
- (264) Godchot and Cauquil, *Bull. soc. chim.*, [4], 43, 520-1 (1928).
- (265) Bedos, *Compt. rend.*, 181, 117-9 (1925); *Chem. Abstr.*, 19, 3266 (1925).
- (266) Conant and Kirner, *J. Am. Chem. Soc.*, 46, 232-52 (1924).
- (267) Bedos, *Bull. soc. chim.*, [4], 39, 674-90 (1926).

- (268) Godchot and Bedos, *Compt. rend.*, 178, 1374-5 (1924).
(269) Cook, Hewett, and Lawrence, *J. Chem. Soc.*, 1936, 71-80.
(270) Mousseron and Du, *Bull. soc. chim.*, [5], 15, 91-6 (1948).
(271) Grignard, French Patent 348,957, Nov. 10, 1904; *J. Soc. Chem. Ind.*, 24, 559 (1905).
(272) Grignard, German Patent 164,883, Nov. 16, 1905; *Chem. Zentr.*, 1905, 11, 1751.
(273) Grignard, *Bull. soc. chim.*, [4], 1, 247-8 (1907).
(274) Urushibara and Chuman, *Bull. Chem. Soc. Japan*, 22, 69-74 (1949); *Chem. Abstr.*, 44, 1124 (1950).
(275) Chuman, *J. Chem. Soc. Japan, Pure Chem. Sect.*, 70, 253-7 (1949); *Chem. Abstr.*, 45, 6651 (1951).
(276) Ostrogovich, *Chem.-Ztg.*, 36, 738-9 (1912); *Chem. Zentr.*, 1912, 11, 607.
(277) Meyer and Nabe, *J. prakt. Chem.*, [2], 82, 521-38 (1910).
(278) van der Zanden, *Rec. trav. chim.*, 57, 233-47 (1938).
(279) van der Zanden, *Rec. trav. chim.*, 58, 181-92 (1939).
(280) van der Zanden and de Vries, *Rec. trav. chim.*, 69, 569-73 (1950).
(281) Thorne, Hennion, and Nieuwland, *J. Am. Chem. Soc.*, 58, 796-7 (1936).
(282) Vavon and Mottez, *Bull. soc. chim.*, [5], 11, 196 (1944).
(283) Kirrmann, *Compt. rend.*, 182, 1629-31 (1926); *Chem. Abstr.*, 20, 3155 (1926).
(284) Prévost, Gaudemar, and Honigberg, *Compt. rend.*, 230, 1186-8 (1950); *Chem. Abstr.*, 45, 1497 (1951).
(285) Lawrence and Shelton, *Ind. Eng. Chem.*, 42, 136-40 (1950).
(286) Letsinger and Traynham, *J. Am. Chem. Soc.*, 72, 849-52 (1950).
(287) Campbell and Eby, *J. Am. Chem. Soc.*, 62, 1798-800 (1940).
(288) Berlande, *Bull. soc. chim.*, [5], 9, 641-2, 642-4, 644-53 (1942).
(289) Pudovik, and Vinokurova, *J. Gen. Chem. (U.S.S.R.)*, 19, 1882-90 (1949); *Chem. Abstr.*, 44, 1896 (1950).
(290) Pourrat, *Compt. rend.*, 228, 1031-3 (1949).
(291) Kirrmann, *Bull. soc. chim.*, [4], 47, 834-47 (1930).
(292) von Braun and Kühn, *Ber.*, 58B, 2168-73 (1925).
(293) Prévost, *Bull. soc. chim.*, [4], 49, 1372-81 (1931).

CHAPTER XVII

Allylic Rearrangements in Grignard Reactions *

The so-called allylic rearrangements of Grignard reagents have been observed in connection with the reactions of Grignard reagents prepared from halides of two general classes: (1) arylmethyl halides, and (2) substituted allyl halides, of which the butenyl halides have been most extensively studied. In reality the two types of reaction have little in common, and their co-classification must be regarded as based chiefly on formal considerations. For that reason the two kinds of reactions, although included in one chapter in deference to popular classification, are discussed separately.

"ABNORMAL" REACTIONS OF ARYLMETHYLMAGNESIUM HALIDES

Although Grignard¹ had erroneously reported the product of the reaction of benzylmagnesium chloride with "trioxymethylene" as phenethyl alcohol, Tiffeneau and Delange² showed that the major product of the reaction is o-tolylmethanol. At the time they made the sapient comment, apparently rather generally ignored by subsequent investigators other than Tschitschibabin,³ and Johnson⁴ that "this particular condensation is of the same type as that whereby the primary aromatic alcohols are obtained from formaldehyde and arylhydroxylamines or sodium phenoxides."

In Table XVII-I are summarized most of the reported "abnormal" reactions of benzylmagnesium chloride and some of its analogs. No attempt

* For discussions of the general subject of allylic rearrangements see: Wheland, "Advanced Organic Chemistry," John Wiley & Sons, Inc., New York, 2nd ed., 1949, pp. 535-44; Young, "Allylic rearrangements during the synthesis of organic compounds," *Record of Chemical Progress*, 11, 129-35 (1950); Young, "Organic reaction mechanisms with allylic compounds," *J. Chem. Education*, 27, 357-64 (1950); Prévost, "La transposition allylique. Généralités. Essais d'interprétation théorique," *Bull. soc. chim.*, [5], 18, C 1-9 (1951). For a review of allylic Grignard reactions see: Kirrmann, "Le rôle des organo-magnésiens dans la transposition allylique," *Bull. soc. chim.*, [5], 18, C 9-13 (1951).

¹ Grignard, *Bull. soc. chim.*, [3], 29, 953-4 (1903).

² Tiffeneau and Delange, *Compt. rend.*, 137, 573-5 (1903); *J. Chem. Soc.*, 86, 1, 48 (1904).

³ Tschitschibabin, *Ber.*, 42, 3469-79 (1909).

⁴ Johnson, *J. Am. Chem. Soc.*, 55, 3029-32 (1933).

TABLE XVII-I

SOME REACTIONS OF BENZYL GRIGNARD REAGENTS AND THEIR ANALOGS

[A plus sign (+) indicates that a product is reported but that the yield is not stated; a plus sign with asterisk (+*) indicates the principal product of the reaction; a plus sign with dagger (+†) indicates a product reported to be present in small amount; a plus sign with two-handled dagger (+‡) indicates a product reported to be present in trace amount.]

RMgX	Co-reactant	"Normal" Product (%)	"Abnormal" Product(s)		Ref.
			Ortho (%)	Para (%)	
(β -C ₄ H ₃ O)CH ₂ MgCl §	CO ₂	1.7	26.8	...	16
(β -C ₄ H ₃ O)CH ₂ MgCl §	HCHO	...	33.4	...	16
(α -C ₄ H ₃ S)CH ₂ MgCl ¶	CO ₂	29.1	15.6	...	18,17
(α -C ₄ H ₃ S)CH ₂ MgCl ¶	ClCO ₂ C ₂ H ₅	0	72	...	18,17
(α -C ₄ H ₃ S)CH ₂ MgCl ¶	HCHO	...	49	...	18
(α -C ₄ H ₃ S)CH ₂ MgCl ¶	CH ₃ COCl	...	31-34	...	18
(α -C ₄ H ₃ S)CH ₂ MgCl ¶	(CH ₂) ₂ O	...	39	...	18
(α -C ₄ H ₃ S)CH ₂ MgCl ¶	(CH ₃ CO) ₂ O	...	25 ‡	...	18
(β -C ₄ H ₃ S)CH ₂ MgBr **	CO ₂	...	12.5 ††	...	19
(α -C ₅ H ₄ N)CH ₂ MgX ††	CH ₃ COCl	+	...	...	20
(α -C ₅ H ₄ N)CH ₂ MgX ††	(CH ₂) ₂ O	+	...	...	20
(α -C ₅ H ₅ S)CH ₂ MgBr §§	CO ₂	...	+	...	21
2,6-Cl ₂ C ₆ H ₃ CH ₂ MgCl	CO ₂	+	...	...	10
2,6-Cl ₂ C ₆ H ₃ CH ₂ MgCl	ClCO ₂ CH ₃	+	...	...	10

§ β -C₄H₃O = 3-furyl; the "ortho" product is the α (2) derivative.

¶ α -C₄H₃S = 2-thienyl; the "ortho" product is the β (3) derivative.

‡ A product believed to be 1,3-bis-(2-thienyl)propene is also reported (31.0%).

** β -C₄H₃S = 3-thienyl; the "ortho" product is the α (2) derivative.

†† This is the overall yield based on (β -C₄H₃S)CH₂Cl; the method employed for the preparation of the Grignard reagent leads chiefly to Wurtz product.

‡‡ α -C₅H₄N = 2-pyridyl; X = Br, I.

§§ α -C₅H₅S = 5-methyl-2-thienyl; the "ortho" product is the β (3) derivative.

TABLE XVII-I (Continued)

RMgX	Co-reactant	"Normal" Product	"Abnormal" Product(s)		Ref.
		(%)	Ortho (%)	Para (%)	
2,6-Cl ₂ C ₆ H ₃ CH ₂ MgCl	CH ₃ COCl	...	...	+	10
2,6-Cl ₂ C ₆ H ₃ CH ₂ MgCl	(CH ₃ CO) ₂ O	+	...	...	10
2-ClC ₆ H ₄ CH ₂ MgCl	CO ₂	+	...	...	10
2-ClC ₆ H ₄ CH ₂ MgCl	ClCO ₂ CH ₃	+	...	...	10
2-ClC ₆ H ₄ CH ₂ MgCl	CH ₃ COCl	...	+	...	10
2-ClC ₆ H ₄ CH ₂ MgCl	(CH ₃ CO) ₂ O	...	+	...	10
C ₆ H ₅ CH ₂ MgCl	Br ₂	63	...	...	9
C ₆ H ₅ CH ₂ MgCl	SO ₂	+	...	...	28
C ₆ H ₅ CH ₂ MgCl	(C ₂ H ₅) ₂ SO ₄	+	0	0.4-5.0	14
C ₆ H ₅ CH ₂ MgCl	H ₂ NCI	92	0	...	11
C ₆ H ₅ CH ₂ MgCl	CO ₂	+	...	...	1,9
C ₆ H ₅ CH ₂ MgCl	CO ₂	40	0	...	10
C ₆ H ₅ CH ₂ MgCl	ClCO ₂ CH ₃	+†	+	...	10
C ₆ H ₅ CH ₂ MgCl	ClCO ₂ C ₂ H ₅	+	+	...	5,6,10
C ₆ H ₅ CH ₂ MgCl	ClCO ₂ C ₂ H ₅	+	ca. 20	+† (?)	9
C ₆ H ₅ CH ₂ MgCl	(C ₂ H ₅ O) ₂ CO	+	...	...	10
C ₆ H ₅ CH ₂ MgCl	HCO ₂ C ₂ H ₅	+	+	+	9
C ₆ H ₅ CH ₂ MgCl	HCHO	...	40	...	23,1
C ₆ H ₅ CH ₂ MgCl	(HCHO) _x	+	42	...	22
C ₆ H ₅ CH ₂ MgCl	CH ₃ COCl	+	+†	...	9
C ₆ H ₅ CH ₂ MgCl	CH ₃ COCl	...	18	...	15
C ₆ H ₅ CH ₂ MgCl	CH ₃ COCl	...	24	...	10
C ₆ H ₅ CH ₂ MgCl	(CH ₂) ₂ O	+	...	+	5,9
C ₆ H ₅ CH ₂ MgCl	CH ₃ CHO	+	+	...	13
C ₆ H ₅ CH ₂ MgCl	CH ₃ CHO	32	29§	...	23
C ₆ H ₅ CH ₂ MgCl	(CH ₃ CHO) _x	+	...	...	1
C ₆ H ₅ CH ₂ MgCl	CH ₃ OCH ₂ Cl	+	+	+	7; cf. 8

§The "abnormal" product reported is the glycol, 1-HOCHR'-2-HOCHR'CH₂C₆H₄.

TABLE XVII-I (Continued)

<u>RMgX</u>	<u>Co-reactant</u>	<u>"Normal" Product</u>	<u>"Abnormal" Product(s)</u>		<u>Ref.</u>
		(%)	Ortho (%)	Para (%)	
C ₆ H ₅ CH ₂ MgCl	CH ₃ OCH ₂ Cl	88x	5x	7x	24
C ₆ H ₅ CH ₂ MgCl	CH ₃ OCH ₂ Br	78x-79x	12x-14x	7x-10x	24
C ₆ H ₅ CH ₂ MgCl	CH ₃ OCH ₂ I	88x	6x	6x	24
C ₆ H ₅ CH ₂ MgCl	C ₂ H ₅ CHO	35	62 §	...	23
C ₆ H ₅ CH ₂ MgCl	(CH ₃) ₂ CO	+	...	...	1
C ₆ H ₅ CH ₂ MgCl	C ₂ H ₅ OCH ₂ Cl	53x	16x	31x	9; <i>c.f.</i> 8
C ₆ H ₅ CH ₂ MgCl	C ₂ H ₅ OCH ₂ Cl	92x	2x	6x	24
C ₆ H ₅ CH ₂ MgCl	CH ₃ (CH ₃ O)CHCl	99.0x	0.8x	0.2x	24
C ₆ H ₅ CH ₂ MgCl	(ClCH ₂ CO) ₂ O	...	<i>ca.</i> 42	...	10
C ₆ H ₅ CH ₂ MgCl	(CH ₃ CO) ₂ O	+	<i>ca.</i> 30	...	10
C ₆ H ₅ CH ₂ MgCl	<i>n</i> -C ₃ H ₇ CHO	+	+	...	13
C ₆ H ₅ CH ₂ MgCl	<i>n</i> -C ₃ H ₇ CHO	40	33 §	...	23
C ₆ H ₅ CH ₂ MgCl	<i>i</i> -C ₃ H ₇ CHO	75	13 §	...	23
C ₆ H ₅ CH ₂ MgCl	<i>n</i> -C ₃ H ₇ OCH ₂ Cl	95.0x	2.5x	2.5x	24
C ₆ H ₅ CH ₂ MgCl	<i>n</i> -C ₃ H ₇ (CH ₃ O)CHCl	98x	2x	0	24
C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CN	+	...	...	9
C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ COCl	+	+	...	10
C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CHO	+	...	...	2
C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CHO	+*	+†	+†	3
C ₆ H ₅ CH ₂ MgCl ¶	C ₆ H ₅ CHO	90	...	...	4
C ₆ H ₅ CH ₂ MgCl †	C ₆ H ₅ CHO	40x	60x**	...	4

§ The "abnormal" product reported is the glycol, 1-HOCHR'-2-HOCHR'CH₂C₆H₄.

¶ Slow dropwise addition of aldehyde to Grignard reagent solution.

† Slow addition of Grignard reagent solution to ethereal aldehyde solution.

** The product reported is 1,3-diphenylisochroman. See also: García-Banús and Medrano, *Anales soc. españ. fís. quim.*, 21, 436-63 (1923); *Chem. Abstr.*, 18, 2144 (1924); García-Banús, *Anales soc. españ. fís. quim.*, 26, 372-98 (1928); *Chem. Abstr.*, 23, 2178 (1929).

TABLE XVII-I (Continued)

<u>RMgX</u>	<u>Co-reactant</u>	<u>"Normal" Product</u>		<u>"Abnormal" Product(s)</u>		<u>Ref.</u>
		(%)		Ortho (%)	Para (%)	
C ₆ H ₅ CH ₂ MgCl §	C ₆ H ₅ CHO	84.7		1.7 ¶	...	25
C ₆ H ₅ CH ₂ MgCl †	C ₆ H ₅ CHO	43.7		17.6 ¶	...	25
C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ Cl	65		...	...	9
C ₆ H ₅ CH ₂ MgCl	<i>n</i> -C ₆ H ₁₃ CHO	55		14**	...	23
C ₆ H ₅ CH ₂ MgCl	ClCH ₂ COC ₆ H ₅	+		...	...	9
C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ CO ₂ C ₂ H ₅	71		...	...	10
C ₆ H ₅ CH ₂ MgCl	C ₂ H ₅ (<i>n</i> -C ₄ H ₉)CHCHO	66		6**	...	23
C ₆ H ₅ CH ₂ MgCl	Citronellal ††	+		+**	...	12; cf. 26,27
C ₆ H ₅ CH ₂ MgCl	(C ₆ H ₅) ₂ NCOC1	+		...	...	9
C ₆ H ₅ CH ₂ MgBr	CH ₃ OCH ₂ Cl	79x		13x	8x	24
C ₆ H ₅ CH ₂ MgI	CH ₃ OCH ₂ Cl	84x		7x	9x	24
2-CH ₃ C ₆ H ₄ CH ₂ MgBr	SO ₂	+		...	...	28
2-CH ₃ C ₆ H ₄ CH ₂ MgBr	CO ₂	+		...	...	28
2-CH ₃ C ₆ H ₄ CH ₂ MgBr	(HCHO) _x	1.5		28.5	...	28
2-CH ₃ C ₆ H ₄ CH ₂ MgBr	(CH ₂) ₂ O	...		10x	90x	28
2-CH ₃ C ₆ H ₄ CH ₂ MgBr	CH ₃ OCH ₂ Cl	...		90x	...	28
2-CH ₃ C ₆ H ₄ CH ₂ MgBr	(CH ₃) ₂ CO	+		...	...	29
3-CH ₃ C ₆ H ₄ CH ₂ MgBr	SO ₂	+*		+† (?)	...	28
3-CH ₃ C ₆ H ₄ CH ₂ MgBr	CO ₂	+†		64††	...	31; cf. 28

§ Slow dropwise addition of aldehyde to Grignard reagent solution.

¶ The product reported is 1,3-diphenylisochroman. See also: García-Banús and Medrano, *Anales soc. españ. fís. quim.*, 21, 436-63 (1923); *Chem. Abstr.*, 18, 2144 (1924); García-Banús, *Anales soc. españ. fís. quim.*, 26, 372-98 (1928); *Chem. Abstr.*, 23, 2178 (1929).

† Slow addition of Grignard reagent solution to ethereal aldehyde solution.

** The "abnormal" product reported is the glycol, 1-HOCHR'-2-HOCHR'CH₂C₆H₄.

†† Probably a mixture of H₂C=C(CH₃)(CH₂)₃CH(CH₃)CH₂CHO and (CH₃)₂C=CHCH₂CH₂CH(CH₃)CH₂CHO.

‡ Although Mousseron and Du (28) have reported the *ortho*-rearrangement product as 2,6-dimethylbenzoic acid, Moser and Sause (31) have shown that it is actually the more probable 2,4-dimethylbenzoic acid. Upon purely geometrical grounds this could, of course, be a *para*-rearrangement product, but that seems highly improbable.

TABLE XVII-I (Continued)

<u>RMgX</u>	<u>Co-reactant</u>	<u>"Normal" Product</u> (%)	<u>"Abnormal" Product(s)</u>		<u>Ref.</u>
			Ortho (%)	Para (%)	
3-CH ₃ C ₆ H ₄ CH ₂ MgBr	(HCHO) _x	+	...	...	29
3-CH ₃ C ₆ H ₄ CH ₂ MgBr	CH ₃ CHO	+	...	...	29
3-CH ₃ C ₆ H ₄ CH ₂ MgBr	(CH ₂) ₂ O	45	...	...	28
3-CH ₃ C ₆ H ₄ CH ₂ MgBr	CH ₃ OCH ₂ Cl	+	...	...	28
3-CH ₃ C ₆ H ₄ CH ₂ MgBr	(CH ₃) ₂ CO	+	...	...	28
4-CH ₃ C ₆ H ₄ CH ₂ MgBr	SO ₂	+	...	...	28
4-CH ₃ C ₆ H ₄ CH ₂ MgBr	CO ₂	90 _x	10 _x	...	28
4-CH ₃ C ₆ H ₄ CH ₂ MgBr	(HCHO) _x	7.5	22.5	...	28
4-CH ₃ C ₆ H ₄ CH ₂ MgBr	(CH ₂) ₂ O	80 _x	20 _x	...	28
CH ₃ (C ₆ H ₅)CHMgCl	(HCHO) _x	+	...	...	28
(α -C ₈ H ₅ S)CH ₂ MgCl §	CO ₂	...	ca. 45	...	32
(α -C ₈ H ₅ S)CH ₂ MgCl §	HCHO	...	35	...	32
(α -C ₈ H ₅ S)CH ₂ MgCl §	CH ₃ COC1	...	29	...	32
(α -C ₈ H ₅ S)CH ₂ MgCl §	C ₆ H ₅ CO ₂ C ₂ H ₅	...	23	...	32
(α -C ₈ H ₅ S)CH ₂ MgCl §	C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄	31	...	...	32
(β -C ₈ H ₅ S)CH ₂ MgCl ¶	CO ₂	16	56	...	33
(β -C ₈ H ₅ S)CH ₂ MgCl ¶	ClCO ₂ C ₂ H ₅	...	43	...	33
(β -C ₈ H ₅ S)CH ₂ MgCl ¶	HCHO	+	18	...	33
(β -C ₈ H ₅ S)CH ₂ MgCl ¶	(CH ₂) ₂ O	+	+	...	33
(β -C ₈ H ₅ S)CH ₂ MgCl ¶	(C ₆ H ₅) ₂ CO	19	...	...	33
(β -C ₈ H ₅ S)CH ₂ MgCl ¶	C ₆ H ₅ COC ₆ H-2,3,5,6-(CH ₃) ₄	20	...	...	33
3,5-(CH ₃) ₂ C ₆ H ₃ CH ₂ MgBr	(HCHO) _x	...	+	...	33
1-C ₁₀ H ₇ CH ₂ MgCl	H ₂ NCl	47	0	...	11
1-C ₁₀ H ₇ CH ₂ MgCl	CO ₂	59.4	...	...	6
1-C ₁₀ H ₇ CH ₂ MgCl	HCHO	+	...	...	28

§ α -C₈H₅S = 2-thianaphthenyl; the "ortho" product is the β (3) derivative.

¶ β -C₈H₅S = 3-thianaphthenyl; the "ortho" product is the α (2) derivative.

TABLE XVII-I (Continued)

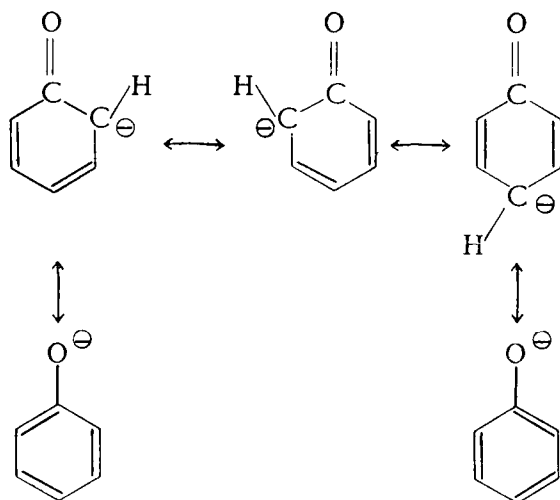
<u>RMgX</u>	<u>Co-reactant</u>	<u>"Normal" Product</u>	<u>"Abnormal" Product(s)</u>		<u>Ref.</u>
		(%)	Ortho (%)	Para (%)	
1-C ₁₀ H ₇ CH ₂ MgCl	HCHO	...	+†	...	6
1-C ₁₀ H ₇ CH ₂ MgCl	(HCHO) _x	45.6	...	...	28
1-C ₁₀ H ₇ CH ₂ MgCl	ClCO ₂ C ₂ H ₅	...	41	...	5,6
1-C ₁₀ H ₇ CH ₂ MgCl	(CH ₃) ₂ SO ₄	55	...	...	6
1-C ₁₀ H ₇ CH ₂ MgCl	C ₆ H ₅ NCO	36	...	...	6
2-C ₁₀ H ₇ CH ₂ MgCl	(HCHO) _x	+	...	...	28
2-C ₁₀ H ₇ CH ₂ MgBr	CO ₂	+	...	...	6
2-C ₁₀ H ₇ CH ₂ MgBr	HCHO	+	?	...	34

REFERENCES FOR TABLE XVII-I

- (1) Tiffeneau and Delange, *Compt. rend.*, 137, 573-5 (1903); *J. Chem. Soc.*, 86,1, 48 (1904).
- (2) Hell, *Ber.*, 37, 453-8 (1904).
- (3) Tschitschibabin, *Ber.*, 42, 3469-79 (1909).
- (4) Schmidlin and García-Banús, *Ber.*, 45, 3193-203 (1912).
- (5) Gilman, Kirby, Fothergill, and Harris, *Proc. Iowa Acad. Sci.*, 34, 221-2 (1927); *Chem. Abstr.*, 22, 4504 (1928).
- (6) Gilman and Kirby, *J. Am. Chem. Soc.*, 51, 3475-8 (1929).
- (7) Bottomley, Lapworth, and Walton, *J. Chem. Soc.*, 1930, 2215-6.
- (8) Baeyer & Co., German Patent 154,658 (1903); *Chem. Zentr.*, 1904,II, 1355; *Friedländer*, 7, 758 (1905).
- (9) Gilman and Kirby, *J. Am. Chem. Soc.*, 54, 345-55 (1932).
- (10) Austin and Johnson, *J. Am. Chem. Soc.*, 54, 647-60 (1932).
- (11) Coleman and Forrester, *J. Am. Chem. Soc.*, 58, 27-8 (1936).
- (12) Young and Siegel, *J. Am. Chem. Soc.*, 66, 354-8 (1944).
- (13) L. G. Davey, as cited by: Johnson, *J. Am. Chem. Soc.*, 55, 3029-32 (1933).
- (14) Burtle and Shriner, *J. Am. Chem. Soc.*, 69, 2059-60 (1947).
- (15) Whitmore and Sloat, *J. Am. Chem. Soc.*, 64, 2968-70 (1942).
- (16) Sherman and Amstutz, *J. Am. Chem. Soc.*, 72, 2195-9 (1950).
- (17) Gaertner, *J. Am. Chem. Soc.*, 72, 4326-7 (1950).
- (18) Gaertner, *J. Am. Chem. Soc.*, 73, 3934-7 (1951).
- (19) Campaigne and LeSuer, *J. Am. Chem. Soc.*, 70, 1555-8 (1948).
- (20) Gilman and Towle, *Rec. trav. chim.*, 69, 428-32 (1950).
- (21) Lecocq and Buu-Hoi, *Compt. rend.*, 224, 658-9 (1947); *Chem. Abstr.*, 41, 4791 (1947).
- (22) Newman, *J. Am. Chem. Soc.*, 62, 2295-300 (1940).
- (23) Siegel, Boyer, and Joy, *J. Am. Chem. Soc.*, 73, 3237-40 (1951).
- (24) Malm and Summers, *J. Am. Chem. Soc.*, 73, 362-3 (1951).
- (25) Siegel, Coburn, and Levering, *J. Am. Chem. Soc.*, 73, 3163-5 (1951).
- (26) Rupe, *Ann.*, 402, 149-86 (1913).
- (27) Gilman and Schulz, *J. Am. Chem. Soc.*, 52, 3588-90 (1930).
- (28) Mousseron and Du, *Bull. soc. chim.*, [5], 15, 91-6 (1948).
- (29) Carré, *Bull. soc. chim.*, [4], 5, 486-9 (1909).
- (30) Carré, *Bull. soc. chim.*, [4], 7, 841-6 (1910).
- (31) Moser and Sause, *J. Org. Chem.*, 15, 631-3 (1950).
- (32) Gaertner, *J. Am. Chem. Soc.*, 74, 766-7 (1952).
- (33) Gaertner, *J. Am. Chem. Soc.*, 74, 2185-8 (1952).
- (34) Sontag, *Ann. chim.*, [11], 1, 359-438 (1934).

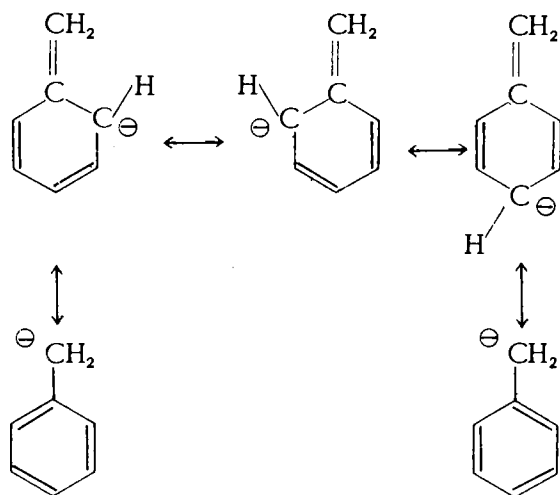
has been made to include all reported "normal" reactions, for it is felt that isolation of the expected product when no special search is made for "abnormal" products is without critical significance.

It will be noted that all the reagents that are reported as reacting "abnormally" with benzylmagnesium chloride belong to classes of compounds which when suitably catalyzed condense with more or less activated benzene nuclei under relatively mild experimental conditions. The substituents that may be regarded as activating in this sense are those which are sometimes described as capable of donating electrons to the aromatic nucleus. The phenolate ion represents an extreme case of activation of this kind; it may be regarded as a resonant structure to which the following canonical forms contribute.



Phenol is in general an excellent Friedel-Crafts reactant; it condenses readily with aldehydes (notably formaldehyde) under a variety of conditions, and the ion, at somewhat elevated temperatures ($120-140^{\circ}$), even condenses with carbon dioxide (Kolbe synthesis).

The analogy between the phenolate and benzyl ions is obvious.



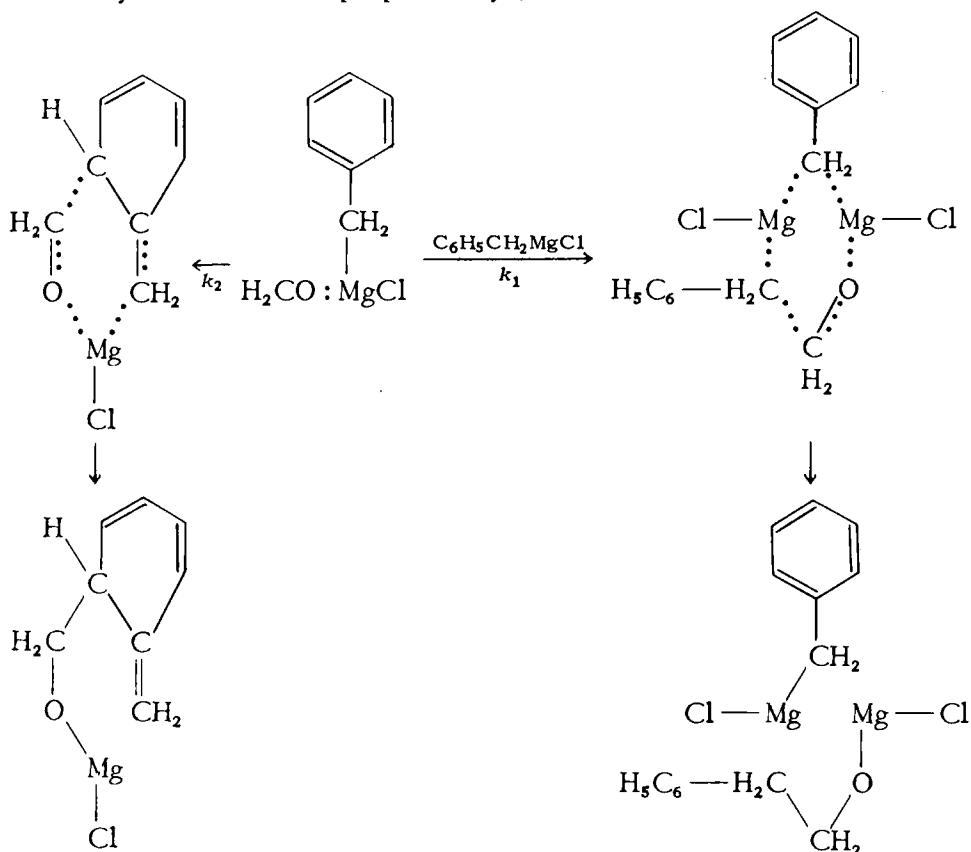
As a benzylmagnesium chloride co-reactant, formaldehyde is unique in that it is highly reactive with respect to both "normal" Grignard reagent addition and benzenoid condensation, and in that steric inhibition is at a minimum with respect to both Grignard reagent addition and *ortho* benzenoid condensation.

If, as there would seem to be every reason to believe, the "normal" addition of a Grignard reagent to an aldehyde has the same mechanism as the "normal" addition of a Grignard reagent to a ketone, the first step in the reaction is almost certainly the formation of a Werner complex of Grignard reagent and aldehyde. Presumably this would also be the first step in an *ortho* condensation reaction. The formation of such a complex undoubtedly facilitates the polarization or ionization* of the Grignard

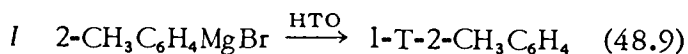
*Ionization does not necessarily imply ionic dissociation. The Werner complex may well exist in the form of an ion-pair.

reagent (which would favor condensation by activating the benzene ring) and probably activates the aldehyde with respect to both the condensation and "normal" addition reactions. The condensation reaction is probably an intracomplex reaction; the "normal" addition probably consists in the reaction of the complex with a second molecule of Grignard reagent.* The major product would be determined by the relative rates of the two competing reactions.

Reduced to its simplest possible terms in the interests of clarity,[†] the case of the formaldehyde reaction might be formulated as follows (essentially in the manner proposed by Johnson^{4,5}):



The fate of the hydrogen atom attached to the carbon atom at which *ortho* condensation takes place has been determined in part by tritium tracer experiments performed by A. R. Van Dyken⁶ of the Argonne National Laboratory. Among others, the following series of reactions was carried out. The tritium content of the product in each case is indicated parenthetically in terms of μ curies per mmole.

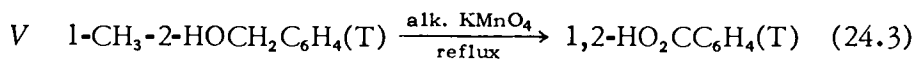
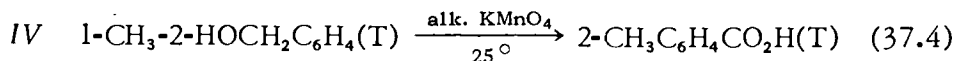
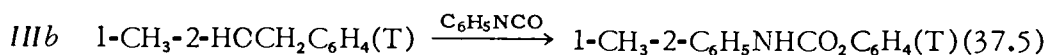
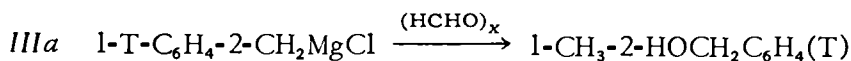
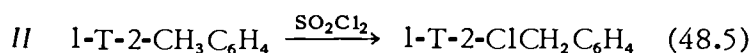


* See Chapter VI, The "Normal" Addition Reactions.

[†] See Chapter IV, Constitution and Dissociation of Grignard Reagents.

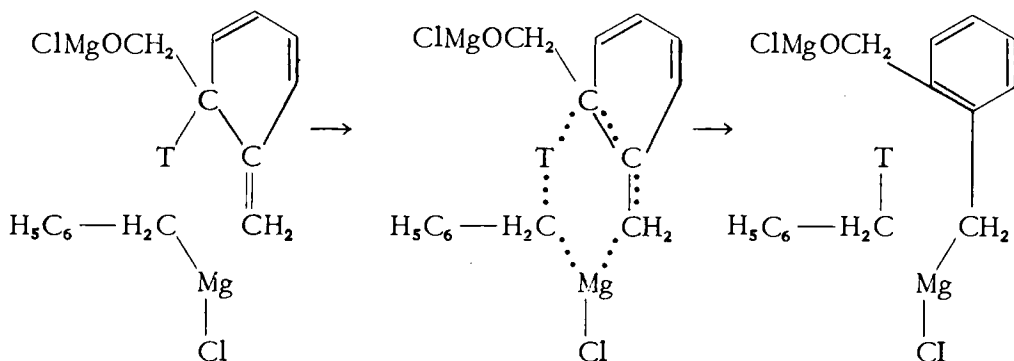
⁵ Johnson, Chapter 25 of Gilman's "Organic Chemistry," John Wiley & Sons, Inc., New York, 2nd ed., 1943, Vol. II, pp. 1879-82.

⁶ Van Dyken, Report to the Organochemical Seminar of the University of Chicago, March 7, 1951.



In addition, it was found that the toluene formed in the reaction had a tritium content corresponding to 53.0 μ curies per mmole.

From these data it is evident that, as might be expected, approximately half the *ortho* condensation takes place at the tritium-substituted carbon atom. It is further apparent that the initial condensation product is an "active" hydrogen (or tritium) compound that reacts fairly readily with excess Grignard reagent. This reaction might well take place in such manner as to lead directly to the formation of a rearranged Grignard reagent.



It is also evident, however, that some hydrogen (or tritium) rearrangement must take place directly. It seems more probable that this is an intermolecular rearrangement than that it is a 1,3 intramolecular shift.

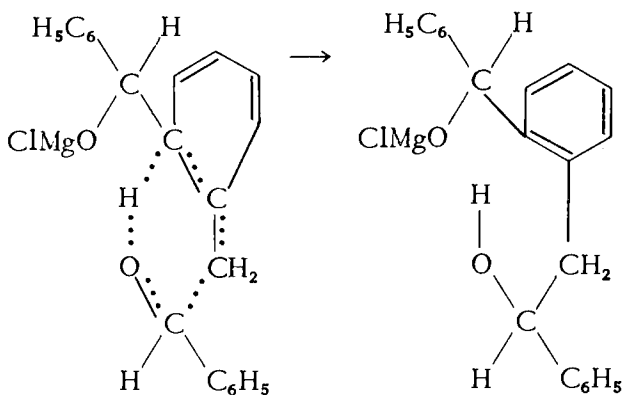
Whereas formaldehyde reactions are necessarily conducted in the presence of an excess of Grignard reagent,* it is obvious that the rate of the *ortho* condensation reaction (k_2) must be considerably greater than that of the "normal" addition reaction (k_1).

Benzaldehyde and the higher aliphatic aldehydes undergo the *ortho* condensation with benzylmagnesium chloride to the greatest extent when the aldehyde is present in excess, and then two molecules of aldehyde condense with one of Grignard reagent. For example, when the "normal" order of addition of benzaldehyde to benzylmagnesium chloride is employed (*i.e.*, when the Grignard reagent is present in excess) the "nor-

*Even the pure liquid formaldehyde of Walker, *J. Am. Chem. Soc.*, 55, 2821-6 (1935), (relatively stable at -80°) polymerizes rapidly in ethereal solution at 0° , so that under no ordinary experimental conditions is it possible to introduce an excess of monomeric formaldehyde into a homogeneous Grignard reaction system.

mal" addition product (1,2-diphenylethanol) is obtained in *ca.* 90 percent yield; when the order of addition is reversed the yield of "normal" addition product is materially lowered, and that of the product resulting from *ortho* condensation (1,3-diphenylisochroman) may exceed it.^{7,8}

It seems probable that the first step in isochroman formation is *ortho* condensation, and that the second molecule of benzaldehyde then reacts either directly with the "active" hydrogen compound initially formed or with the Grignard reagent derived from it.



In the case of the benzaldehyde reaction the glycolic product undergoes cyclodehydration very readily, and the isochroman is the product isolated. The "abnormal" glycolic products of the aliphatic aldehydes (other than formaldehyde) may be isolated by the observation of suitable experimental precautions (notably the exclusion of acid during distillation^{9,10}).

Various hypotheses relating to "abnormal" condensation reactions of benzylmagnesium halides have been discussed by Austin and Johnson,¹¹ by Johnson (*loc. cit.*^{4,5}), and by Siegel *et al.* (*loc. cit.*^{8,9,10}), but the present authors perceive no compelling reason to reject in principle the suggestion originally advanced by Tiffeneau and Delange (*loc. cit.*²) and endorsed by Tschitschibabin (*loc. cit.*³). Although the reaction mechanisms of the various co-reactants that undergo *ortho* condensations undoubtedly differ from one another in detail, it seems highly probable that they are all rather closely analogous one to another.

It is perhaps of incidental interest, worthy of passing mention, that carbon dioxide, which reacts "normally" with benzylmagnesium chloride to yield phenylacetic acid, and which had therefore been regarded by some organic chemists as a typically "normal" co-reactant has been found to undergo *ortho* condensation readily with some of the benzyl ana-

⁷ Schmidlin and García-Banús, *Ber.*, 45, 3193-203 (1912). See also: García-Banús and Medrano, *Anales. soc. españ. fís. quim.*, 21, 436-63; *Chem. Abstr.*, 18, 2144 (1924); García-Banús, *Anales soc. españ. fís. quim.*, 26, 372-98 (1928); *Chem. Abstr.*, 23, 2178 (1929).

⁸ Siegel, Coburn, and Levering, *J. Am. Chem. Soc.*, 73, 3163-5 (1951).

⁹ Young and Siegel, *J. Am. Chem. Soc.*, 66, 354-8 (1944).

¹⁰ Siegel, Boyer, and Joy, *J. Am. Chem. Soc.*, 73, 3237-40 (1951).

¹¹ Austin and Johnson, *J. Am. Chem. Soc.*, 54, 647-60 (1932).

logs (see Table XVII-I). Even the phenyl ring of the benzyl group, when activated by the introduction of a *meta* methyl substituent, is able to participate to some degree in *ortho* condensation with carbon dioxide. The "abnormal" product in this case had been reported by Mousseron and Du¹² as 2,6-dimethylbenzoic acid, but has been found by Moser and Sause¹³ to be in fact 2,4-dimethylbenzoic acid. *A priori* this would appear more probable on the grounds (a) that the *ortho* position *para* to the substituent methyl group should be the more highly activated of the two, and (b) that this position should be less subject to steric inhibition.

Schmidlin¹⁴ supposed that he had succeeded in preparing the Grignard reagent of triphenylmethyl chloride in two isomeric forms: namely, an unstable *alpha* quinonoid form, and a stable *beta* form of the expected configuration. He believed that the *alpha* form could be converted into the *beta* form by heating, and that the two forms could be distinguished by their behavior toward benzaldehyde or cinnamaldehyde. Toward these reagents the *beta* form was supposed to be unreactive, whereas the *alpha* form was supposed to undergo *para*-condensation.

As Tschitschibabin¹⁵ showed, Schmidlin's conclusions were based in part upon faulty observation and in part upon gratuitous assumption. Schmidlin's *alpha* form, which supposedly reacted with water to form "triphenylmethyl," was in reality a mixture of a little triphenylmethylmagnesium chloride with a considerable amount of hexaphenylethane. Tschitschibabin found that the Grignard reagent reacts "normally" with benzoic ester to give an 80 percent yield of crude benzopinacolin, and with carbon dioxide to give a 90 percent yield of triphenylacetic acid. As he pointed out, there is no reason to suppose that the *para* condensation of benzaldehyde with this reagent differs fundamentally from the similar *ortho* condensation of formaldehyde with benzylmagnesium chloride.

In the case of triphenylmethylmagnesium chloride it is obvious that steric hindrance to *ortho* condensation is prohibitive. If the "normal" aldehyde addition is indeed trimolecular (as seems most probable), steric inhibition of this reaction must also be considerable. Tschitschibabin, however, did detect small quantities of the "normal" addition product with benzaldehyde in addition to the major *para* condensation product. As in the case of the benzylmagnesium halides, *para* condensation probably results from interaction of two Werner-complex aggregates.

"ABNORMAL" REACTIONS OF SUBSTITUTED ALLYLMAGNESIUM HALIDES

The earliest reported allylic rearrangement (involving the Grignard reagent) of which the present authors have knowledge is a hybrid reaction

¹² Mousseron and Du, *Bull. soc. chim.*, [5], 15, 91-6 (1948).

¹³ Moser and Sause, *J. Org. Chem.*, 15, 631-3 (1950).

¹⁴ Schmidlin, *Ber.*, 39, 4183-98 (1906); 40, 2316-29 (1907); 41, 426-30 (1908); Schmidlin and Hodgson, *ibid.*, 41, 430-7 (1908).

¹⁵ Tschitschibabin, *Ber.*, 40, 3965-70 (1907); 42, 3469-72 (1909).

in the sense that both Grignard reagent and co-reactant are allylic; namely, that of magnesium with cinnamyl chloride (Rupe and Bürgin¹⁶). The reaction was conducted under conditions which might be expected to lead chiefly to a "Wurtz product." Doubtless some of the product formed is attributable to a Wurtz reaction, analogous to that whereby biphenyl is formed in the reaction of magnesium with bromobenzene. Probably the major portion of the product, however, is attributable to reaction of the cinnamyl halide with its own Grignard reagent. According to Rupe and Bürgin, only about 25-30 percent of the product obtained consisted of bicinnamyl (1,6-diphenyl-1,5-hexadiene); the remainder, which they described as 1,4-diphenyl-1-hexene, must in reality have been chiefly 1,4-diphenyl-1,5-hexadiene.¹⁷ The respective yields reported are not quantitatively significant, for they total somewhat more than 100 percent, but the ratio between products is probably approximately correct for the conditions imposed.

von Braun and Köhler¹⁸ have claimed that bicinnamyl is obtainable in better yield from cinnamyl bromide than from cinnamyl chloride, but this claim is not confirmed by the reports of Kuhn and Winterstein¹⁹ or Koch.²⁰ On the basis of ultraviolet absorption spectrum measurements, Koch estimates that the product he obtained by treating 111 g. of cinnamyl chloride with 9 g. of metallic magnesium consisted of 3-5 percent *meso*- α,α' -divinylbibenzyl (I), 20 percent *trans*-bicinnamyl (II), and 75 percent isobicinnamyl (1,4-diphenyl-1,5-hexadiene) (III). An experiment conducted similarly with cinnamyl bromide yielded 1 percent I, 10 percent II and eighty-nine percent III. When distilled under reduced pressure or when heated to 150°, I rearranges to yield approximately three parts of II and two parts of III.

Similar reactions have been studied by other investigators. For example, Prévost and Richard²¹ report that 1-bromo-2-penten ϵ , when treated with magnesium, yields 3,7-decadiene, 3-ethyl-1,5-octadiene, and 3,4-diethyl-1,5-hexadiene in the approximate proportions 0.295:0.652:0.052, together with a small amount of unidentified material. The aggregate yield of identified material is about 90 percent. According to Lespieau and Heitzmann,²² "crotyl bromide" reacts with magnesium to form a mixture of isomeric "dicrotyls." There is reasonable doubt that the bromides used in these studies were pure isomers.²³

¹⁶ Rupe and Bürgin, *Ber.*, 43, 172-8 (1910).

¹⁷ Cf. Prévost, *Bull. soc. chim.*, [4], 49, 1372-81 (1931); Gilman and Harris, *J. Am. Chem. Soc.*, 54, 2072-5 (1932); Harris, *Iowa State Coll. J. Sci.*, 6, 425-8 (1932); *Chem. Abstr.*, 27, 279 (1933).

¹⁸ von Braun and Köhler, *Ber.*, 51, 79-96 (1918).

¹⁹ Kuhn and Winterstein, *Helv. Chim. Acta*, 11, 87-116 (1928).

²⁰ Koch, *J. Chem. Soc.*, 1948, 1111-7.

²¹ Prévost and Richard, *Bull. soc. chim.*, [4], 49, 1368-72 (1931).

²² Lespieau and Heitzmann, *Compt. rend.*, 200, 1077-80 (1935); *Chem. Abstr.*, 29, 4325 (1935); *Bull. soc. chim.*, [5], 3, 273-7 (1936).

²³ See: Young, Richards, and Azorlosa, *J. Am. Chem. Soc.*, 61, 3070-4 (1939).

Henne *et al.*²⁴ have studied the reactions of magnesium with "isomeric crotyl chlorides." From "secondary crotyl chloride" (3-chloro-1-butene) they obtained an aggregate yield of about 67 percent of identified products in the proportions indicated: 2,6-octadiene (0.045); 3-methyl-1,5-heptadiene (0.850); 3,4-dimethyl-1,5-hexadiene (0.104). From "primary crotyl chloride" (1-chloro-2-butene) they obtained an aggregate yield of about 54 percent of two isomers plus "a little" of the third. Assuming that "a little" signifies something of the order of 1 percent, the reported distribution would be approximately: 2,6-octadiene (0.018); 3-methyl-1,5-heptadiene (0.909); 3,4-dimethyl-1,5-hexadiene (0.073). From a crude mixture of the isomeric chlorides they obtained an aggregate yield of 67 percent of identified products in the proportions indicated: 2,6-octadiene (0.060); 3-methyl-1,5-heptadiene (0.895); 3,4-dimethyl-1,5-hexadiene (0.045). In view of the experimental difficulties attendant upon quantitative separation of isomeric product mixtures of this kind, it is difficult to decide whether or not the apparent differences in product distributions are in fact real.

As might be expected, the reactions of magnesium with allyl chloride and with β -methallyl chloride (2-methyl-3-chloro-1-propene) gave the respective "normal" products: 1,5-hexadiene (60 percent) and 2,5-dimethyl-1,5-hexadiene (65 percent) (Henne *et al.*, *loc. cit.*²⁴).

Entirely aside from the possibility of such complications as functional exchange, experiments like those just described offer no basis for decision as to whether the "abnormalities" of the reactions are attributable to the allylic Grignard reagents or the allylic co-reactants. However, thanks in large part to the studies of Young and co-workers, there is considerable available evidence on both points.

According to Gilman *et al.*,²⁵ the Grignard reagent derived from cinnamyl chloride reacts with carbon dioxide, with phenyl isocyanate, or with ethyl chloroformate as though it had the constitution $\text{C}_6\text{H}_5\text{CH}(\text{MgCl})\text{CH}=\text{CH}_2$. However, the yields of the isocyanate and chloroformate products are not stated, and those claimed for β -methylatropic acid* are 11.4–27.1 percent. It is also reported by Ou Kuin-Houo²⁶ that "cinnamylmagnesium bromide" reacts similarly with acetaldehyde, though yields are not stated.

²⁴Henne, Chanan, and Turk, *J. Am. Chem. Soc.*, 63, 3474–6 (1941).

²⁵Gilman and Harris, *J. Am. Chem. Soc.*, 49, 1825–8 (1927); 53, 3541–6 (1931); Gilman, Kirby, Fothergill, and Harris, *Proc. Iowa Acad. Sci.*, 34, 221–2 (1927); *Chem. Abstr.*, 22, 4504 (1928); Harris, *Iowa State Coll. J. Sci.*, 6, 425–8 (1932); *Chem. Abstr.*, 27, 279 (1933).

* Actually, the product initially formed is the labile phenylvinylacetic acid, $\text{C}_6\text{H}_5\text{CH}(\text{CO}_2\text{H})\text{CH}=\text{CH}_2$ (m.p. 23–24°), which is easily converted by heating, or by warming with acids or alkalis, to the stable β -methylatropic acid, $\text{C}_6\text{H}_5\text{C}(\text{CO}_2\text{H})=\text{CHCH}_3$ (m.p. 135–136°).

²⁶Ou Kuin-Houo, *Ann. chim.*, [11], 13, 175–241 (1940).

On the other hand, Coleman and Forrester²⁷ report a 14 percent yield of cinnamylamine from the reaction of this Grignard reagent with chloroamine.

On the basis of the assumptions (1) that the Grignard reagent is an equilibrium mixture of isomeric forms, and (2) that the products of hydrolysis may be expected to reflect reliably the composition of the isomeric mixture, Young *et al.*²⁸ conclude that "cinnamylmagnesium chloride" comprises approximately 75 percent of the secondary reagent and 25 percent of the primary reagent. These assumptions will be considered in connection with the following discussion of the analogous butenylmagnesium halides for which more extensive data are available.

Reported data concerning the reactions of butenyl Grignard reagents are summarized in Table XVII-II. The first four items of Table XVII-II are included, with somewhat more detail, in Table XVII-III, which records reactions of butenyl Grignard reagents with "active hydrogen" compounds.

As a preliminary to consideration of the reactions of butenyl Grignard reagents it may be well to take note of a few experimental observations which supply something in the way of general background. Winstein and Young²⁹ claim to have effected the first isolation of pure crotyl and α -methallyl (methylvinylcarbinyl) bromides. They find that both bromides approach equilibrium (*ca.* 85.5 percent primary, 14.5 percent secondary) very rapidly (<5 minutes) at 100°, and more slowly (*ca.* 10 days) at room temperature. This, taken in conjunction with the fact that Young and Lane³⁰ have found that all investigated methods of converting crotyl or α -methallyl alcohols to bromides are productive of isomeric mixtures, makes it seem highly probable that all early literature reports of reactions of butenylmagnesium halides, whatever their designations, relate to reagents prepared from halide mixtures.³¹ This point, however, is not so significant as it might at first appear, for, according to Young, Winstein, and Prater,³² butenylmagnesium bromides, whether prepared from one of the pure isomers or from an isomeric mixture, always yield on acid hydrolysis the same mixture of 1-butene (56.4 ± 2.0 percent), *cis*-2-butene (26.5 ± 1.4 percent), and *trans*-2-butene (17.2 ± 3.0 percent). Actually, the relative proportions of butenes vary somewhat with the conditions of the hydrolysis, as is shown in a subsequent study by Wilson, Roberts, and Young³³ (Table XVII-III).

²⁷ Coleman and Forrester, *J. Am. Chem. Soc.*, 58, 27-8 (1936).

²⁸ Young, Ballou, and Nozacki, *J. Am. Chem. Soc.*, 61, 12-15 (1939); Campbell and Young, *ibid.*, 69, 688-90 (1947).

²⁹ Winstein and Young, *J. Am. Chem. Soc.*, 58, 104-7 (1936).

³⁰ Young and Lane, *J. Am. Chem. Soc.*, 59, 2051-6 (1937).

³¹ See also: Young, Richards, and Azorlosa, *J. Am. Chem. Soc.*, 61, 3070-4 (1939).

³² Young, Winstein, and Prater, *J. Am. Chem. Soc.*, 58, 289-91 (1936).

³³ Wilson, Roberts, and Young, *J. Am. Chem. Soc.*, 72, 215-7 (1950).

Table XVII-II
SOME REACTIONS OF BUTENYL GRIGNARD REAGENTS

Reagent	Co-reactant *	Product(s) (% yield)		Ref.
		Crotyl	α -Methallyl	
C ₄ H ₇ MgBr	H ⁺	43.6	56.4	1
C ₄ H ₇ MgCl	H ⁺	45.8	54.2	2
C ₄ H ₇ MgBr	H ⁺	49.7-7.8	50.3-92.2	3
(C ₄ H ₇) ₂ Mg	H ⁺	55.5	44.5	4
C ₄ H ₇ MgBr	O ₂	ca. 45 [†]	ca. 55 [†]	5
C ₄ H ₇ MgCl	CO ₂ ↓	...	70.0	6
C ₄ H ₇ MgBr	CO ₂ ↓	...	75.0	7
C ₄ H ₇ MgBr	CO ₂ §	...	63.0¶	7
(C ₄ H ₇) ₂ Mg	CO ₂ ↓	...	37.0	6
C ₄ H ₇ MgBr	HCHO	none	50.0	6
C ₄ H ₇ MgBr	(HCHO) _x	...	38.0	15
C ₄ H ₇ MgBr	CH ₃ CHO	...	+	8
C ₄ H ₇ MgBr	CH ₃ CHO	...	84.0	6
C ₄ H ₇ MgBr	H ₂ C=CHCHO	...	+	8
C ₄ H ₇ MgBr	H ₂ C=CHCH ₂ Br	ca. 45 [†]	ca. 55 [†]	9
C ₄ H ₇ MgBr	C ₂ H ₅ CHO	...	25.0	8
C ₄ H ₇ MgBr	(CH ₃) ₂ CO	...	81.0	6
C ₄ H ₇ MgBr	HCO ₂ C ₂ H	...	+	10
C ₄ H ₇ MgBr	ClCH ₂ O- <i>n</i> -C ₄ H ₉	...	+	11

* For the first four items in this table, designation of the co-reactant as the hydrogen ion probably presents too simple a picture (see Table XVII-III).

† The statement published is to the effect that "...reaction of the Grignard reagent with oxygen to form alcohols, or with allyl bromide to form heptadienes, leads to the same mixture of primary and secondary radicals as that produced by the action of water (1,2)."

‡ By the method of Fieser, Holmes, and Newman, *J. Am. Chem. Soc.*, 58, 1055 (1936), *i.e.*, method IV, Table XIII-I.

§ By the method of Arnold, Bank, and Liggett, *J. Am. Chem. Soc.*, 63, 3444-6 (1941), *i.e.*, method VI, Table XIII-I.

¶ In addition to the acid, an unidentified dibutenyl ketone was obtained in 13 percent yield.

Table XVII-II (Continued)

Reagent	Co-reactant	Product(s) (% yield)		Ref.
		Crotyl	α -Methallyl	
C ₄ H ₇ MgBr	C ₆ H ₅ NCO	...	+	10
C ₄ H ₇ MgBr	C ₆ H ₅ CHO	...	+	8
C ₄ H ₇ MgBr	(<i>i</i> -C ₃ H ₇) ₂ CO	13.4	75.6	12
C ₄ H ₇ MgCl	(<i>i</i> -C ₃ H ₇) ₂ CO	5.1	79.9	12
C ₄ H ₇ MgBr	HC(OC ₂ H ₅) ₃	...	+	10
C ₄ H ₇ MgBr	HC(OC ₂ H ₅) ₃	...	73.0	15
C ₄ H ₇ MgBr	<i>i</i> -C ₃ H ₇ CO- <i>t</i> -C ₄ H ₉	...	74.0	13
C ₄ H ₇ MgBr	(<i>t</i> -C ₄ H ₉) ₂ CO	69.0	...	13
C ₄ H ₇ MgBr	CH ₃ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	...	76.0	14
C ₄ H ₇ MgBr	(C ₆ H ₅) ₂ CO	...	+*	13
C ₄ H ₇ MgBr	<i>i</i> -C ₃ H ₇ COC ₆ H ₂ -2,4,6-(CH ₃) ₃	+ (?) [†]	+ [†]	13

* On heating, the addition product yields 77 percent *trans*-2-butene and 23 percent *cis*-2-butene; presumably the product is therefore the α -methallyl derivative.

[†] Thermal decomposition of the product is reported as yielding 6 ± 5 percent 1-butene, 24 ± 5 percent *trans*-2-butene, and 70 ± 5 percent *cis*-2-butene; presumably the product is therefore substantially the α -methallyl derivative.

REFERENCES FOR TABLE XVII-II

- (1) Young, Winstein, and Prater, *J. Am. Chem. Soc.*, 58, 289-91 (1936).
- (2) Young and Eisner, *J. Am. Chem. Soc.*, 63, 2113-5 (1941).
- (3) Wilson, Roberts, and Young, *J. Am. Chem. Soc.*, 72, 215-7 (1950).
- (4) Young and Pokras, *J. Org. Chem.*, 7, 233-40 (1942).
- (5) Siegal, M. A. Dissertation, University of California, L. A., 1939, as cited by Young and Pokras (4) and Young and Roberts (14b).
- (6) Roberts and Young, *J. Am. Chem. Soc.*, 67, 148-50 (1945).
- (7) Lane, Roberts, and Young, *J. Am. Chem. Soc.*, 66, 543-5 (1944).
- (8) Ou Kuin-Houo, *Ann. chim.*, [11], 13, 175-241 (1940).
- (9) Wax, M. A. Dissertation, University of California, L. A., 1940, as cited by Young and Pokras (4).
- (10) Young and Roberts, *J. Am. Chem. Soc.*, 68, 649-52 (1946).
- (11) Young, Roberts, and Wax, *J. Am. Chem. Soc.*, 67, 841-3 (1945).
- (12) Young and Roberts, *J. Am. Chem. Soc.*, 67, 319-21 (1945).
- (13) Wilson, Roberts, and Young, *J. Am. Chem. Soc.*, 72, 218-9 (1950).
- (14) Young and Roberts, *J. Am. Chem. Soc.*, (a) 66, 2131 (1944); (b) 68, 1472-5 (1946).
- (15) Inhoffen, Bohlman, and Reinefeld, *Chem. Ber.*, 82, 313-6 (1949).

TABLE XVII-III

BUTENES FROM THE REACTION OF BUTENYLMAGNESIUM BROMIDE WITH "ACTIVE HYDROGEN" COMPOUNDS *

Reagent	Solvent	<i>trans</i> -2-Butene (%)	<i>cis</i> -2-Butene (%)	1-Butene (%)
(2 N H ₂ SO ₄) [†]	(None) [†]	(20.4) [†]	(25.4) [†]	(54.2) [†]
(2 N H ₂ SO ₄) [‡]	(None) [‡]	(23.2 ± 0.4) [‡]	(32.2 ± 0.3) [‡]	(44.5 ± 0.3) [‡]
2 N H ₂ SO ₄ [§]	None [§]	17.2 ± 3.0 [§]	26.5 ± 1.4 [§]	56.4 ± 2.0 [§]
2 N H ₂ SO ₄	None	21.1 ± 0.7	28.6 ± 0.7	50.3 ± 1.6
2 N H ₂ SO ₄	Ethyl ether	13.5 ± 0.5	16.6 ± 0.1	69.9 ± 0.4
2 N H ₂ SO ₄	Butyl ether	13.1 ± 1.4	14.3 ± 0.8	72.9 ± 2.1
2 N H ₂ SO ₄	Benzene	13.6	10.0	76.4
2 N H ₂ SO ₄	Heptane	12.4 ± 0.7	11.0 ± 0.9	76.5 ± 1.5
HCl	Ethyl ether	10.1 ± 2.4	6.5 ± 1.9	83.4 ± 4.1
NH ₄ I	Ethyl ether	28.4 ± 0.6	30.1 ± 0.1	41.5 ± 0.5
CH ₃ CO ₂ H	None	15.2	19.1	65.7
CH ₃ CO ₂ H	Ethyl ether	10.0 ± 0.9	10.1 ± 1.1	80.0 ± 0.5
ClCH ₂ CO ₂ H	Ethyl ether	3.3 ± 0.8	4.8 ± 2.6	92.2 ± 1.6
Cl ₃ CCO ₂ H	Ethyl ether	7.7 ± 0.6	6.2 ± 0.1	86.3 ± 0.7
C ₂ H ₅ OH	None	19.8 ± 0.4	25.4 ± 0.2	54.8 ± 0.6
C ₆ H ₅ C≡CH [¶]	Ethyl ether [¶]	1.0 [¶]	5.4 [¶]	93.6 [¶]

* Except as otherwise specified, the data in this table are taken from the paper of Wilson, Roberts, and Young, *J. Am. Chem. Soc.*, 72, 215-7 (1950). Butene analysis by infra-red absorption. Average deviations from the mean of several (2-6) experiments are given.

[†] These data are for butenylmagnesium chloride, Young and Eisner, *J. Am. Chem. Soc.*, 63, 2113-5 (1941). Butene analysis by bromination, and fractionation of dibromides.

[‡] These data are for dibutenylmagnesium, Young and Pokras, *J. Org. Chem.*, 7, 233-40 (1942). Butene analysis by bromination, and fractionation of dibromides.

[§] These data are for butenylmagnesium bromide, Young, Winstein, and Prater, *J. Am. Chem. Soc.*, 58, 289-91 (1936). Butene analysis by bromination, and fractionation of dibromides.

[¶] These data are taken from the paper of Young and Roberts, *J. Am. Chem. Soc.*, 68, 1472-5 (1946). Butene analysis by infra-red absorption.

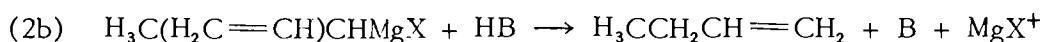
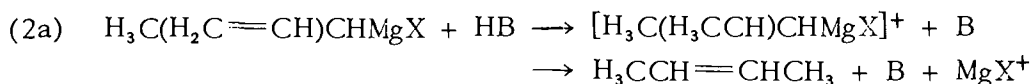
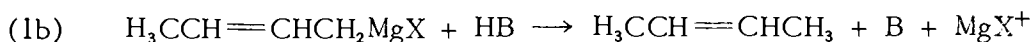
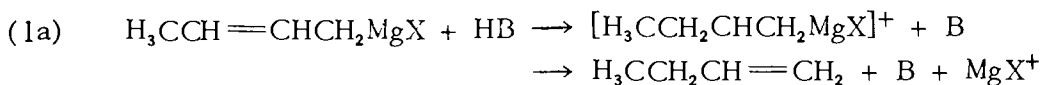
TABLE XVII-III (Continued)

<u>Reagent</u>	<u>Solvent</u>	<u><i>trans</i>-2-Butene (%)</u>	<u><i>cis</i>-2-Butene (%)</u>	<u>1-Butene (%)</u>
$s\text{-C}_4\text{H}_9(i\text{-C}_3\text{H}_7)_2\text{COH}$	Ethyl ether	17.8 ± 0.6	13.7 ± 1.0	68.5 ± 1.6
$2,4,6\text{-(CH}_3)_3\text{C}_6\text{H}_2\text{COCH(C}_6\text{H}_5)_2$	Ethyl ether + benzene	2.7 ± 2.8	35.9 ± 7.2	61.4 ± 4.4
$(\text{C}_6\text{H}_5\text{SO}_2)_2\text{CH}_2$	Ethyl ether	x^*	$32-x^*$	68^*

* Butene analysis by bromination, and fractionation of dibromides.

In some of the earlier papers of their series on allylic rearrangements Young and co-workers³⁴ marshalled arguments in support of the hypothesis that a butenyl Grignard reagent is an equilibrium mixture of isomeric forms, and assumed, sometimes implicitly, occasionally explicitly, that the composition of the butene mixture obtained upon acid hydrolysis of the reagent is indicative of the equilibrium composition.

The reason why the latter assumption is untenable is precisely the same as the reason why the hydrogen chloride cleavage of unsymmetrical organomercurials cannot be expected to assign allylic radicals to their proper places in the "electronegativity series," and has been stated by Kharasch and Swartz.³⁵ It has now been recognized by Young *et al.*³⁶ Briefly, it is that olefinic compounds in general, and allylic organometallics in particular, are bases in the Brønsted sense. Hence allylic organometallic compounds are capable of undergoing acidic cleavage by a mechanism (1a, 2a) other than the "normal" one (1b, 2b) which may be regarded as general for organometallics.



In more recent papers Young *et al.*³⁷ have abandoned the equilibrium mixture hypothesis, and have concluded that the available experimental data are consistent with the supposition that butenyl Grignard reagents are essentially crotylmagnesium halides. In order to minimize tiresome expansion of an unprofitable discussion, it is here categorically asserted that the problem of the constitution of allylic Grignard reagents is but one of many structural problems incapable of purely chemical solution. Detailed explicit substantiation of this assertion should be unnecessary; the following examination of possibilities is sufficiently illustrative.

A. *The butenyl Grignard reagent is essentially a crotylmagnesium halide.*

1. For the reason already stated acid hydrolysis of the reagent yields inconclusive results.

2. To account for the products obtained upon reaction with carbonyl compounds, among which carbon dioxide may be included, it is assumed

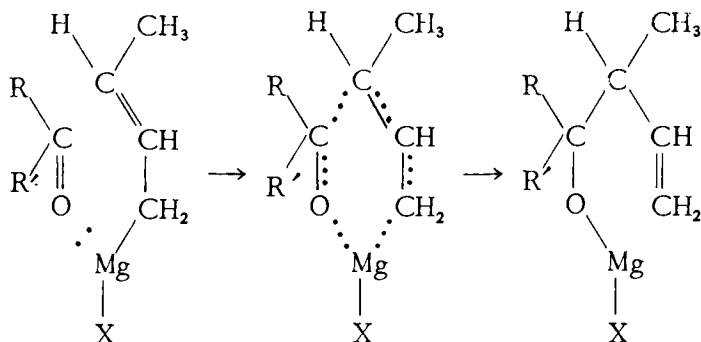
³⁴See, especially: Young and Winstein, *J. Am. Chem. Soc.*, 58, 441-3 (1936); Young, Kaufman, Loshokoff, and Pressman, *ibid.*, 60, 900-3 (1938); Young and Pokras, *J. Org. Chem.*, 7, 233-40 (1942).

³⁵Kharasch and Swartz, *J. Org. Chem.*, 3, 405-8 (1938).

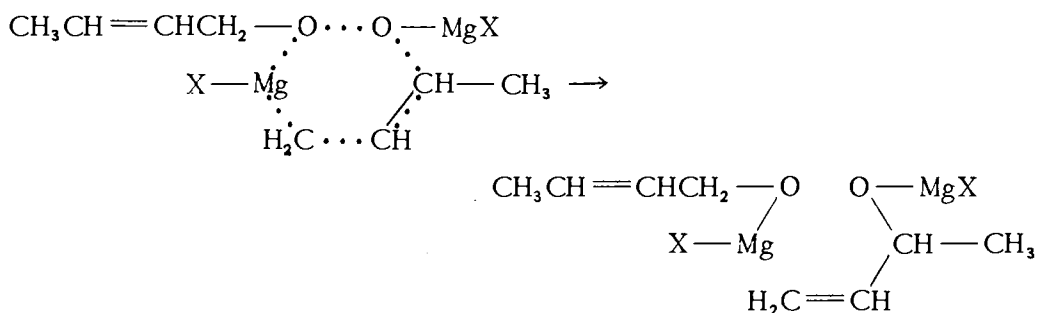
³⁶Wilson, Roberts, and Young, *J. Am. Chem. Soc.*, 72, 215-7 (1950).

³⁷See, e.g.: Young and Roberts, *J. Am. Chem. Soc.*, 68, 649-52 (1946); *ibid.*, 68, 1472-5 (1946); Wilson, Roberts, and Young, *loc. cit.*³⁶

that allylic Grignard reagents are capable of reacting by a mechanism other than any that may be reasonably postulated for the "normal" reactions of the general run of Grignard reagents. A reaction in which a single molecule of Grignard reagent serves both as activator of the carbonyl group and as co-reactant has been suggested by Young and Roberts (*loc. cit.*³⁷); it appears to embody nothing inherently improbable.



3. To account for the mixture of alcohols obtained upon oxygenation of the reagent it is assumed that reduction of the peroxy compound presumably formed in the initial stage of the reaction (see Chapter XX, Oxygen) takes place by a mechanism other than the usual one.



B. The butenyl Grignard reagent is essentially an α -methallylmagnesium halide.

1. For the reason already stated the acid hydrolysis of the reagent yields inconclusive results.

2. It is assumed that reaction with carbonyl compounds takes place by the "normal" mechanism (see Chapter VI, The "Normal" Addition Reactions).

3. It is assumed that in the oxygenation reaction the reduction of the peroxy intermediate compound takes place by a mechanism other than the usual one.

C. The butenyl Grignard reagent is an equilibrium mixture of isomeric forms.

1. For the reason already stated the acid hydrolysis of the reagent yields inconclusive results.

2. It is assumed that reaction with carbonyl compounds takes place by the "normal" mechanism, but that the secondary form of the Grignard reagent is considerably more reactive than the primary form. This is in

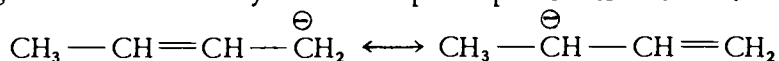
accord with the findings of Kharasch and Weinhouse³⁸ concerning the relative reactivities of Grignard reagents toward ketones. Judged on the basis of the probable electronegativities of the respective organic radicals, a crotyl-magnesium halide should have a potential reactivity approximating that of the corresponding benzyl reagent; an α -methallylmagnesium halide should have a potential reactivity somewhat greater than that of the corresponding *t*-butyl reagent. In both cases the unsaturated reagent should be subject to somewhat less steric inhibition than the saturated reagent to which it is compared.

Interconversion of forms would be effected rapidly through an exchange process of the sort responsible for establishment of the Schlenk equilibrium (see Chapter IV, The Schlenk Equilibrium).

If, on the other hand, it be assumed that reaction follows the mechanism proposed for crotylmagnesium bromide, it must be assumed that the primary form of the reagent is considerably more reactive than the secondary form. There would appear to be no *a priori* reason for such an assumption other than the invocation of a rather dubious steric effect.

3. Whether the oxygenation reaction is assumed to follow the "normal" or a special mechanism, mixtures of alcohols would be expected. In the "normal" reaction the secondary form of the reagent might be expected to be the more effective in the reduction stage (Wuyts³⁹ and Kharasch and Reynolds⁴⁰; see Chapter XX, Oxygen).

Recapitulation. Underlying all the foregoing discussion relating to structure is the implicit assumption that the Grignard reagent may be regarded as an essentially covalent compound. To the extent that the reagent is ionized, however, it cannot be said to have any structure in the classical sense, for the butenyl ion is a resonant aggregate to which the following forms undoubtedly make the principal contributions.



This point was appreciated by Prévost,⁴¹ who, as early as 1927 coined the term "synionie" to designate the phenomenon.

Although it must be reiterated that this type of constitutional problem does not admit of purely chemical solution, the present authors are inclined to believe that, to the extent that the Grignard reagent may be regarded as a covalent compound, or that ion-pairs may be regarded as having definite points of mutual attachment, the following hypotheses seem reasonable and are consistent (though not uniquely so) with the known chemical facts.

(1) The butenyl Grignard reagents (and probably most analogous allylic Grignard reagents) are equilibrium mixtures of isomeric forms. (2) Under

³⁸ Kharasch and Weinhouse, *J. Org. Chem.*, 1, 209-30 (1936).

³⁹ Wuyts, *Bull. soc. chim. Belg.*, 36, 222-38 (1927).

⁴⁰ Kharasch and Reynolds, *J. Am. Chem. Soc.*, 65, 501-4 (1943).

⁴¹ Prévost, *Compt. rend.*, 185, 132-4 (1927).

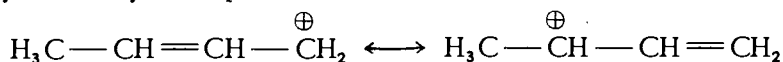
ordinary reaction conditions equilibrium is rapidly established by exchange of the Schlenk type. (3) In many reactions either form of the Grignard reagent is potentially capable of reacting simultaneously by (a) the "normal" mechanism and (b) a special allylic mechanism. Although it is possible that in some instances one mechanism may be preferred to the virtual exclusion of the others, it is also conceivable that in other instances as many as four (or more) mechanisms may operate simultaneously. (4) The preferred mechanism (or mechanisms) will be determined in part by the nature of the co-reactant, but may, in some cases, be materially affected by the reaction conditions. (For example bimolecular mechanisms would be favored over trimolecular mechanisms by operation in the presence of an excess of co-reactant, and *vice versa*.)

It may be remarked in passing that, in general, the formation of a so-called "abnormal" product in the reaction of an allylic Grignard reagent need not necessarily involve any "rearrangement" at all in the ordinary sense of the term.

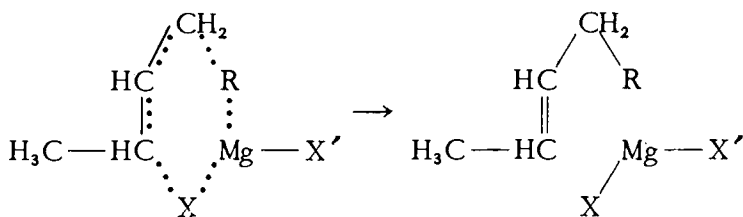
REACTIONS OF GRIGNARD REAGENTS WITH ALLYLIC CO-REACTANTS

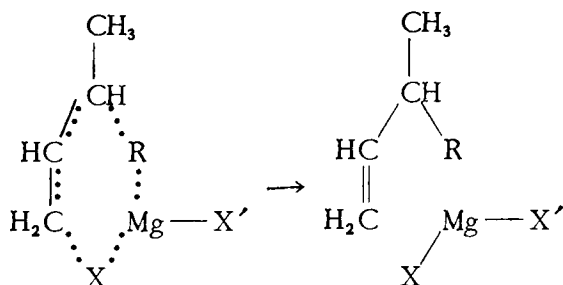
Allylic Halides. Although they are, in the opinion of the present authors, devoid of critical theoretical significance, reported data on the reactions of Grignard reagents with allylic halides are assembled for the convenience of the reader in Table XVII-IV. In some instances there is reasonable doubt of the purity of the isomer reported. Even when a pure and relatively stable isomer is employed, however, it seems highly probable that rearrangement would take place readily in the presence of magnesium halide.

As has been pointed out in Chapter XVI the reaction of a Grignard reagent with an organic halide may be regarded as a special type of solvolysis. To the extent that such a solvolysis might proceed by an S_N1 mechanism allylic isomers would lose their individuality, for either isomer of a pair would give rise to the same resonant cation. For example, the butenyl ion may be represented as follows.



To the extent that reaction might take place through a bimolecular mechanism involving a cyclic intermediate, isomer individuality would be preserved, but, for the reasons outlined, the existent data are scarcely a reliable guide to what actually does take place.





On the whole it seems probable that two or more mechanisms may operate simultaneously in such reactions.

Butenyl esters. The suggestion of a special mechanism has also been advanced to account for the behavior of crotyl and α -methallyl mesitoates when treated with phenylmagnesium bromide.⁴² Crotyl mesitoate undergoes cleavage to yield crotylbenzene only, whereas α -methallyl mesitoate yields crotylbenzene and α -methallylbenzene in approximately the same proportions as either of the isomeric butenyl chlorides. These reactions are discussed in more detail in Chapter VIII, Ester Cleavages.

⁴²(a) Arnold and Liggett, *J. Am. Chem. Soc.*, 67, 337-8 (1945). (b) Arnold and Searles, *ibid.*, 71, 2021-3 (1949). (c) Wilson, Roberts, and Young, *ibid.*, 71, 2019-20 (1949).

TABLE XVII-IV
REACTIONS OF GRIGNARD REAGENTS WITH ALLYLIC HALIDES

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₃H₄Cl₂			
H ₂ C=CHCHCl ₂	CH ₃ MgBr	CH ₄ + C ₂ H ₆ + C ₂ H ₅ CH=CHCl + C ₂ H ₅ CH=CHCH ₃ + H ₂ C=CHCH(CH ₃) ₂ + CH ₃ (H ₂ CCH=CH) ₂ CH ₃ + high-boiling hydrocarbons	1
H ₂ C=CHCHCl ₂	<i>n</i> -C ₃ H ₇ MgBr	C ₆ H ₁₄ + <i>n</i> -C ₄ H ₉ CH=CHCl (<i>ca.</i> 25%) + <i>n</i> -C ₃ H ₇ CH=CH- <i>n</i> -C ₄ H ₉ + C ₁₂ H ₂₂ (30%)	2
H ₂ C=CHCHCl ₂	<i>i</i> -C ₃ H ₇ MgBr	C ₃ H ₈ + C ₆ H ₁₄ + <i>i</i> -C ₄ H ₉ CH=CHCl + <i>i</i> -C ₄ H ₉ CH=CH- <i>i</i> -C ₃ H ₇ + H ₂ C=CHCH(<i>i</i> -C ₃ H ₇) ₂ + <i>i</i> -C ₃ H ₇ (H ₂ CCH=CH) ₂ - <i>i</i> -C ₃ H ₇ + high-boiling hydrocarbons	1
H ₂ C=CHCHCl ₂	<i>n</i> -C ₄ H ₉ MgBr	C ₄ H ₁₀ + C ₈ H ₈ + <i>n</i> -C ₅ H ₁₁ CH=CHCl + <i>n</i> -C ₅ H ₁₁ CH=CH- <i>n</i> -C ₄ H ₉ + H ₂ C=CHCH(<i>n</i> -C ₄ H ₉) ₂ + <i>n</i> -C ₄ H ₉ (H ₂ CCH=CH) ₂ - <i>n</i> -C ₄ H ₉ + high-boiling hydrocarbons	1
H ₂ C=CHCHCl ₂	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ CH=CHCl ("poor yield") + tar	3
ClCH=CHCH ₂ Cl	CH ₃ MgBr	CH ₄ + C ₂ H ₆ + C ₂ H ₅ CH=CHCl + C ₂ H ₅ CH=CHCH ₃ + H ₂ C=CHCH(CH ₃) ₂ + CH ₃ (H ₂ CCH=CH) ₂ CH ₃ + high-boiling hydrocarbons	1
ClCH=CHCH ₂ Cl	<i>n</i> -C ₃ H ₇ MgBr	C ₆ H ₁₄ + <i>n</i> -C ₄ H ₉ CH=CHCl ("very little") + <i>n</i> -C ₃ H ₇ CH=CH- <i>n</i> -C ₄ H ₉ + C ₁₂ H ₂₂ (>30%)	2
ClCH=CHCH ₂ Cl	<i>i</i> -C ₃ H ₇ MgBr	C ₃ H ₈ + C ₆ H ₁₄ + <i>i</i> -C ₄ H ₉ CH=CHCl + <i>i</i> -C ₄ H ₉ CH=CH- <i>i</i> -C ₃ H ₇ + H ₂ C=CHCH(<i>i</i> -C ₃ H ₇) ₂ + <i>i</i> -C ₃ H ₇ (H ₂ CCH=CH) ₂ - <i>i</i> -C ₃ H ₇ + high-boiling hydrocarbons	1
ClCH=CHCH ₂ Cl	<i>n</i> -C ₄ H ₉ MgBr	C ₄ H ₁₀ + C ₈ H ₁₈ + <i>n</i> -C ₅ H ₁₁ CH=CHCl + <i>n</i> -C ₅ H ₁₁ CH=CH- <i>n</i> -C ₄ H ₉ + H ₂ C=CHCH(<i>n</i> -C ₄ H ₉) ₂ + <i>n</i> -C ₄ H ₉ (H ₂ CCH=CH) ₂ - <i>n</i> -C ₄ H ₉ + high-boiling hydrocarbons	1
ClCH=CHCH ₂ Cl	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ CH ₂ CH=CHCl ("high yield")	4
ClCH=CHCH ₂ Cl	C ₆ H ₅ MgBr	C ₆ H ₅ CH ₂ CH=CHCl (<i>ca.</i> quant.)	4

TABLE XVII-IV (Continued)

Halide	RMgX	Product(s)	Ref.
C₃H₄Cl₂ (cont.)			
ClCH=CHCH ₂ Cl	2-CH ₃ C ₆ H ₄ MgBr	2-CH ₃ C ₆ H ₄ CH ₂ CH=CHCl ("high yield")	4
ClCH=CHCH ₂ Cl	4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ CH ₂ CH=CHCl ("high yield")	4
ClCH=CHCH ₂ Cl	4-CH ₃ OC ₆ H ₄ MgBr	4-CH ₃ OC ₆ H ₄ CH ₂ CH=CHCl ("high yield")	4
ClCH=CHCH ₂ Cl	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ MgBr	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ CH ₂ CH=CHCl ("high yield")	4
ClCH=CHCH ₂ Cl	2-CH ₃ -5- <i>i</i> -C ₃ H ₇ C ₆ H ₃ MgBr	2-CH ₃ -5- <i>i</i> -C ₃ H ₇ C ₆ H ₃ CH ₂ CH=CHCl ("high yield")	4
C₃H₄Br₂			
BrCH=CHCH ₂ Br	CH ₃ MgBr	CH ₄ + C ₂ H ₆ + C ₄ H ₇ Br + (H ₂ C=CH—) ₂ (5%) + C ₈ H ₁₄ + C ₁₀ H ₁₈ or C ₁₀ H ₁₆	2,5
BrCH=CHCH ₂ Br	C ₂ H ₅ MgBr	BrCH=CH- <i>n</i> -C ₃ H ₇ + C ₇ H ₁₄ (30%)	2,5
BrCH=CHCH ₂ Br	<i>n</i> -C ₃ H ₇ MgBr	C ₆ H ₁₄ (5%) + <i>n</i> -C ₃ H ₇ CH=CH- <i>n</i> -C ₄ H ₉ (47%) + C ₁₂ H ₂₂ + high-boiling unsaturates	2,5
BrCH=CHCH ₂ Br	C ₆ H ₅ MgBr	BrCH=CHCH ₂ C ₆ H ₅ (50%)	2,6
C₃H₄ICl			
ClCH=CHCH ₂ I	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₄ H ₉ CH=CHCl (?)* + unidentified products	3
C₄H₅Cl			
H ₂ C=C=CHCH ₂ Cl	CH ₃ MgCl	H ₂ C=C(CH ₃)CH=CH ₂ (14.7%)	7,8
H ₂ C=C=CHCH ₂ Cl	CH ₃ MgI	H ₂ C=C(CH ₃)CH=CH ₂ (23.5%)	7,8
H ₂ C=C=CHCH ₂ Cl	<i>n</i> -C ₄ H ₉ MgBr	H ₂ C=C(<i>n</i> -C ₄ H ₉)CH=CH ₂ (13.1%)	7,8
H ₂ C=C=CHCH ₂ Cl	C ₆ H ₅ MgBr	H ₂ C=C=CHCH ₂ C ₆ H ₅ (4.0-7.2%) + H ₂ C=C(C ₆ H ₅)CH=CH ₂ (8.4-9.2%) + [H ₂ C=C(C ₆ H ₅)CH=CH ₂] ₂ (25.3-26.7%)	7,8
H ₂ C=C=CHCH ₂ Cl	C ₆ H ₅ CH ₂ MgCl	H ₂ C=C=CHCH ₂ CH ₂ C ₆ H ₅	8
H ₂ C=C=CHCH ₂ Cl	<i>n</i> -C ₇ H ₁₅ MgCl	H ₂ C=C(<i>n</i> -C ₇ H ₁₅)CH=CH ₂ (21.0%)	7,8

* Not positively identified; small yield if any.

TABLE XVII-IV (Continued)

<u>Halide</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₅Cl₃			
Cl ₂ C=C(CH ₃)CH ₂ Cl	CH ₃ MgBr	C ₂ H ₆ + [(CH ₃) ₂ C=C(CH ₃)CH ₂ —] ₂ + Cl ₂ C=C(CH ₃)CH ₂ C(CH ₃) ₂ C(CH ₃)=CH ₂ + Cl ₂ C=C(CH ₃)CH ₂ CH ₂ C(CH ₃)=C(CH ₃) ₂	9
C₄H₆Br₂			
BrCH=C(CH ₃)CH ₂ Br	C ₂ H ₅ MgBr	C ₈ H ₁₆ (30%) + C ₆ H ₁₁ Br + C ₁₀ H ₁₇ Br	2
C₄H₇Cl			
CH ₃ CH=CHCH ₂ Cl	H ₂ C=CHCH ₂ MgCl	(H ₂ C=CHCH ₂) ₂ CH ₂ (>50.8%) + H ₂ C=CHCH(CH ₃)CH ₂ CH=CH ₂ (<3.2%)	10
CH ₃ CH=CHCH ₂ Cl	H ₂ C=CHCH ₂ MgBr	CH ₃ CH=CHCH ₂ CH ₂ CH=CH ₂ (53.5%)	11
CH ₃ CH=CHCH ₂ Cl	Butenyl-MgBr	(CH ₃ CH=CHCH ₂ —) ₂ (8.6%) + H ₂ C=CHCH(CH ₃)CH ₂ CH=CHCH ₃ (59.0%) + [H ₂ C=CHCH(CH ₃)—] ₂ (5.0%)	10
CH ₃ CH=CHCH ₂ Cl	<i>n</i> -C ₄ H ₉ MgCl	CH ₃ CH=CH- <i>n</i> -C ₅ H ₁₁ (60%) + H ₂ C=CHCH(CH ₃)- <i>n</i> -C ₄ H ₉ (10%)	12
CH ₃ CH=CHCH ₂ Cl	C ₆ H ₅ MgBr	CH ₃ CH=CHCH ₂ C ₆ H ₅ (46 ± 3%) + H ₂ C=CHCH(CH ₃)C ₆ H ₅ (14 ± 2%)	13
CH ₃ CH=CHCH ₂ Cl + CH ₃ (H ₂ C=CH)CHCl	<i>n</i> -C ₄ H ₉ MgCl	H ₂ C=CHCH(CH ₃)CH ₂ CH=CHCH ₃ (6x%) + H ₂ C=CHCH(CH ₃)- <i>n</i> -C ₄ H ₉ (9x%) + CH ₃ CH=CH- <i>n</i> -C ₅ H ₁₁ (85x%)	14
CH ₃ CH=CHCH ₂ Cl (41%) + CH ₃ (H ₂ C=CH)CHCl (59%)	C ₆ H ₅ MgBr	CH ₃ CH=CHCH ₂ C ₆ H ₅ (81 ± 3x%) + H ₂ C=CHCH(CH ₃)C ₆ H ₅ (19 ± 2x%)	13
CH ₃ (H ₂ C=CH)CHCl	H ₂ C=CHCH ₂ MgCl	(H ₂ C=CHCH ₂) ₂ CH ₂ (42.4%) + H ₂ C=CHCH(CH ₃)CH ₂ CH=CH ₂ (13.2%)	10
CH ₃ (H ₂ C=CH)CHCl	Butenyl-MgBr	(CH ₃ CH=CHCH ₂ —) ₂ (2.3%) + H ₂ C=CHCH(CH ₃)CH ₂ CH ₂ CH=CH ₂ (65.4%) + [H ₂ C=CHCH(CH ₃)—] ₂ (8.4%)	10

TABLE XVII-IV (Continued)

Halide	RMgX	Product(s)	Ref.
C₄H₇Cl (<i>cont.</i>)			
CH ₃ (H ₂ C=CH)CHCl	C ₆ H ₅ MgBr	CH ₃ CH=CHCH ₂ C ₆ H ₅ (52 ± 4%) + CH ₃ (H ₂ C=CH)CHC ₆ H ₅ (14 ± 2%)	13
C₄H₇Br			
CH ₃ CH=CHCH ₂ Br	C ₆ H ₅ MgBr	CH ₃ CH=CHCH ₂ C ₆ H ₅ (34%)	15
CH ₃ CH=CHCH ₂ Br	C ₆ H ₅ CH ₂ CH ₂ MgBr	H ₂ C=CHCH(CH ₃)CH ₂ CH ₂ C ₆ H ₅	15
CH ₃ CH=CHCH ₂ Br (87%) + CH ₃ (H ₂ C=CH)CHBr (13%)	Butenyl-MgBr	(CH ₃ CH=CHCH ₂ -) ₂ (5.8%) + H ₂ C=CHCH(CH ₃)CH ₂ CH=CHCH ₃ (51.0%) + [H ₂ C=CHCH(CH ₃)-] ₂ (1.2%)	10
CH ₃ CH=CHCH ₂ Br + CH ₃ (H ₂ C=CH)CHBr*	(CH ₂) ₄ CHMgCl	CH ₃ (H ₂ C=CH)CHCH(CH ₂) ₄ + <i>cis</i> - and <i>trans</i> -CH ₃ CH=CHCH ₂ CH(CH ₂) ₄	16
CH ₃ (H ₂ C=CH)CHBr	Butenyl-MgBr	(CH ₃ CH=CHCH ₂ -) ₂ (37.5%) + H ₂ C=CHCH(CH ₃)CH ₂ CH=CHCH ₃ (26.3%) + [H ₂ C=CHCH(CH ₃)-] ₂ (11.3%)	10
CH ₃ (H ₂ C=CH)CHBr	C ₆ H ₅ CH ₂ CH ₂ MgBr	CH ₃ CH=CH(CH ₂) ₃ C ₆ H ₅	15
C₅H₉Cl			
CH ₃ (CH ₃ CH=CH)CHCl	<i>n</i> -C ₃ H ₇ MgCl	CH ₃ (CH ₃ CH=CH)CH- <i>n</i> -C ₃ H ₇	14
C₅H₉Br			
C ₂ H ₅ CH=CHCH ₂ Br	C ₂ H ₅ MgBr ^c	C ₂ H ₅ CH=CH- <i>n</i> -C ₃ H ₇ (16-20%) + (C ₂ H ₅) ₂ CHCH=CH ₂ (60-64%)	18, 17
C ₂ H ₅ CH=CHCH ₂ Br	C ₆ H ₅ MgBr	C ₂ H ₅ CH=CHCH ₂ C ₆ H ₅ (25-33%) + C ₂ H ₅ (C ₆ H ₅)CHCH=CH ₂ (66-75%)	18
CH ₃ (CH ₃ CH=CH)CHBr	CH ₃ MgBr	CH ₃ CH=CH(CH ₃) ₂ CH (57%)	19
CH ₃ (CH ₃ CH=CH)CHBr	<i>n</i> -C ₃ H ₇ MgBr	CH ₃ (CH ₃ CH=CH)CH- <i>n</i> -C ₃ H ₇ (27%)	19

* From the addition of hydrogen bromide to 1,3-butadiene.

TABLE XVII-IV (Continued)

Halide	RMgX	Product(s)	Ref.
C₅H₉Br (<i>cont.</i>)			
CH ₃ (CH ₃ CH=CH)CHBr	<i>n</i> -C ₄ H ₉ MgBr	CH ₃ (CH ₃ CH=CH)CH- <i>n</i> -C ₄ H ₉ (28%)	19
CH ₃ (CH ₃ CH=CH)CHBr	<i>i</i> -C ₄ H ₉ MgBr	CH ₃ (CH ₃ CH=CH)CH- <i>i</i> -C ₄ H ₉ (36%)	19
CH ₃ (CH ₃ CH=CH)CHBr	<i>s</i> -C ₄ H ₉ MgBr	CH ₃ (CH ₃ CH=CH)CH- <i>s</i> -C ₄ H ₉ (8%)	19
CH ₃ (CH ₃ CH=CH)CHBr	<i>t</i> -C ₄ H ₉ MgBr	CH ₃ (CH ₃ CH=CH)CH- <i>t</i> -C ₄ H ₉ (5%)	19
CH ₃ (CH ₃ CH=CH)CHBr	(CH ₂) ₄ CHMgBr	CH ₃ (CH ₃ CH=CH)CHCH(CH ₂) ₄ (15%)	19
C₆H₈Br₂			
(-HC=CHCH ₂ Br) ₂	C ₂ H ₅ MgBr	<i>n</i> -C ₃ H ₇ CH=CHCH(C ₂ H ₅)CH=CH ₂ + (<i>n</i> -C ₃ H ₇ CH=CH-) ₂ + [H ₂ C=CH(C ₂ H ₅)CH-] ₂ + C ₂ H ₅ (<i>n</i> -C ₃ H ₇)CHCH=CHCH=CH ₂ (?) + BrCH ₂ (C ₂ H ₅)CHCH=CHCH=CH ₂ (?) + unidentified products	20
C₇H₁₃ClO			
C ₂ H ₅ OCH ₂ CH ₂ CH=CHCH ₂ Cl	C ₂ H ₅ MgBr	Rec. C ₇ H ₁₃ ClO (18.5%) + C ₂ H ₅ OCH ₂ CH ₂ CH=CH- <i>n</i> -C ₃ H ₇ (43.8%) + H ₂ C=CH(C ₂ H ₅ OCH ₂ CH ₂)(C ₂ H ₅ OCH ₂ CH ₂ CH=CHCH ₂)CH (16.1%)	22
C ₂ H ₅ OCH ₂ CH ₂ CH=CHCH ₂ Cl	<i>n</i> -C ₄ H ₉ MgCl	Rec. C ₇ H ₁₃ ClO (12.0%) + C ₂ H ₅ OCH ₂ CH ₂ CH=CH- <i>n</i> -C ₅ H ₁₁ (54.3%) + H ₂ C=CH(C ₂ H ₅ OCH ₂ CH ₂)(C ₂ H ₅ OCH ₂ CH ₂ CH=CHCH ₂)CH (16.7%)	22
H ₂ C=CH(C ₂ H ₅ OCH ₂ CH ₂)CHCl	C ₂ H ₅ MgBr	Rec. C ₇ H ₁₃ ClO (5.0%) + C ₂ H ₅ OCH ₂ CH ₂ CH=CH- <i>n</i> -C ₃ H ₇ (49.3%) + H ₂ C=CH(C ₂ H ₅ OCH ₂ CH ₂)(C ₂ H ₅ OCH ₂ CH ₂ -CH=CHCH ₂)CH (18.6%)	22
H ₂ C=CH(C ₂ H ₅ OCH ₂ CH ₂)CHCl	<i>n</i> -C ₄ H ₉ MgBr	Rec. C ₇ H ₁₃ ClO (11.3%) + C ₂ H ₅ OCH ₂ CH ₂ CH=CH- <i>n</i> -C ₅ H ₁₁ (53.1%) + H ₂ C=CH(C ₂ H ₅ OCH ₂ CH ₂)(C ₂ H ₅ OCH ₂ CH ₂ CH=CHCH ₂)CH (19.1%)	22

TABLE XVII-IV (Continued)

Halide	RMgX	Product(s)	Ref.
C₉H₉Cl			
C ₆ H ₅ CH=CHCH ₂ Cl	CH ₃ MgBr	C ₆ H ₅ CH=CHC ₂ H ₅ (89%) + (C ₆ H ₅ CH=CHCH ₂ —) ₂ (1%) + C ₆ H ₅ CH=CHCH ₂ CH(C ₆ H ₅)CH=CH ₂ (5%)	21
C₉H₉Br			
C ₆ H ₅ CH=CHCH ₂ Br	C ₂ H ₅ MgBr	C ₆ H ₅ CH=CH- <i>n</i> -C ₃ H ₇ (ca. 50%) + C ₂ H ₅ (C ₆ H ₅)CHCH=CH ₂ (ca. 25%)*	18
C ₆ H ₅ CH=CHCH ₂ Br	C ₂ H ₅ MgBr	C ₂ H ₅ Br (14.0%) + C ₆ H ₅ CH=CHCH ₃ (2.5%) + C ₆ H ₅ CH ₂ CH=CH ₂ (2.5%) + (C ₆ H ₅ CH=CHCH ₂ —) ₂ (4.5%) + C ₂ H ₅ (C ₆ H ₅)CHCH=CH ₂ (23.0%) + C ₆ H ₅ CH=CH- <i>n</i> -C ₃ H ₇ (50.0%) + C ₂ H ₆ (10.0%) + cond'n products †	20
C₉H₁₇Cl			
<i>i</i> -C ₄ H ₉ CH=CH(CH ₃) ₂ CCl + <i>i</i> -C ₃ H ₇ [(CH ₃) ₂ C=CH]CHCl	CH ₃ MgCl	<i>i</i> -C ₄ H ₉ CH=CH- <i>i</i> -C ₄ H ₉ (16.7x%) + <i>i</i> -C ₃ H ₇ [(CH ₃) ₂ C=CH]CHCH ₃ (83.3x%)	14
C₉H₁₇ClO			
<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CHCH ₂ Cl	<i>n</i> -C ₄ H ₉ MgBr	Rec. C ₉ H ₁₇ ClO (13.0%) + <i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CH- <i>n</i> -C ₅ H ₁₁ (43.7%) + H ₂ C=CH(<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂)(<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CHCH ₂)CH (23.2%)	22
<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CHCH ₂ Cl	C ₆ H ₅ MgBr	Rec. C ₉ H ₁₇ ClO (12.5%) + <i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CHCH ₂ C ₆ H ₅ (66.0%) + C ₆ H ₆	22
H ₂ C=CH(<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂)CHCl	<i>n</i> -C ₄ H ₉ MgBr	Rec. C ₉ H ₁₇ ClO (13.8%) + <i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CH- <i>n</i> -C ₅ H ₁₁ (44.1%) + H ₂ C=CH(<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂)(<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CHCH ₂)CH (23.2%)	22
H ₂ C=CH(<i>n</i> -C ₄ H ₉ OCH ₂ CH ₂)CHCl	C ₆ H ₅ MgBr	Rec. C ₉ H ₁₇ ClO (14.5%) + <i>n</i> -C ₄ H ₉ OCH ₂ CH ₂ CH=CHCH ₂ C ₆ H ₅ (67.0%) + C ₆ H ₆	22

* Slow addition of Et₂O-bromide solution to Grignard reagent solution; several hours reflux.

† Addition of bromide to Grignard reagent solution; twelve hours at room temperature.

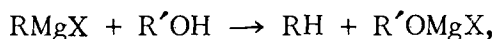
REFERENCES FOR TABLE XVII-IV

- (1) Pourrat, *Compt. rend.*, 228, 1031-3 (1949).
- (2) Kirmann, *Bull. soc. chim.*, [4], 47, 834-47 (1930).
- (3) Kirmann, Pacaud, and Dosque, *Bull. soc. chim.*, [5], 1, 860-71 (1934).
- (4) Bert, *Compt. rend.*, 180, 1504-6 (1925).
- (5) Kirmann, *Compt. rend.*, 182, 1629-31 (1926); *Chem. Abstr.*, 20, 3155 (1926).
- (6) von Braun and Kühn, *Ber.*, 58B, 2168-73 (1925).
- (7) Carothers and Berchet, *J. Am. Chem. Soc.*, 55, 1094-6 (1933).
- (8) Carothers, U. S. Patent 2,072,867, March 9, 1937; *Chem. Abstr.*, 31, P3335 (1937).
- (9) Kirmann and Jacob, *Bull. soc. chim.*, [5], 7, 586-93 (1940).
- (10) Young, Roberts, and Wax, *J. Am. Chem. Soc.*, 67, 841-3 (1945).
- (11) Levy and Cope, *J. Am. Chem. Soc.*, 66, 1684-8 (1944).
- (12) Cleveland, *J. Chem. Phys.*, 11, 1-6 (1943).
- (13) Wilson, Roberts, and Young, *J. Am. Chem. Soc.*, 71, 2019-20 (1949).
- (14) Henne, Chanan, and Turk, *J. Am. Chem. Soc.*, 63, 3474-6 (1941).
- (15) Lawrence and Shelton, *Ind. Eng. Chem.*, 42, 136-40 (1950).
- (16) Plate, Sterligov, and Bazhulin, *J. Gen. Chem. (U.S.S.R.)*, 14, 955-9 (1944); *Chem. Abstr.*, 39, 4594 (1945).
- (17) Prévost, *Compt. rend.*, 187, 946-8 (1928); *Chem. Abstr.*, 23, 2149 (1929).
- (18) Prévost and Daujat, *Bull. soc. chim.*, [4], 47, 588-94 (1930).
- (19) Mulliken, Wakeman, and Gerry, *J. Am. Chem. Soc.*, 57, 1605-7 (1935).
- (20) Prévost, *Bull. soc. chim.*, [4], 49, 1372-81 (1931).
- (21) Kharasch, Lambert, and Urry, *J. Org. Chem.*, 10, 298-306 (1945).
- (22) Pudovik and Vinokurova, *J. Gen. Chem. (U.S.S.R.)*, 19, 1882-90 (1949); *Chem. Abstr.*, 44, 1896 (1950).

CHAPTER XVIII

The Tschugaeff-Zerewitinoff Method for the Determination of "Active" Hydrogen

On the basis of the observation of Tissier and Grignard¹ that organo-magnesium halides react with alcohols and phenols according to the equation



Tschugaeff² suggested the use of Grignard reagents for (1) the detection of hydroxylic compounds and (2) the separation of hydroxylic compounds from hydrocarbons, ethers, and other "indifferent" substances. He further suggested, that with the aid of a suitable gas-measuring device, such as a Knop nitrometer, ethereal methylmagnesium iodide might be employed for the quantitative estimation of dry hydroxylic substances. Tschugaeff published no experimental data, and apparently made no further contribution to the subject; the continued linkage of his name with the method subsequently developed by others is probably attributable to Zerewitinoff's³ insistence on crediting him with the original idea.

Quantitative data were first published by Hibbert and Sudborough,⁴ who, however, in the interests of greater accuracy, found it desirable to modify somewhat the method as originally suggested by Tschugaeff. To avoid the gradual permeation by water of the india-rubber connections of a Knop nitrometer, they substituted a mercury-filled Lunge nitrometer or Hempel burette. To avoid the slow absorption of oxygen by the Grignard reagent, they displaced the air from their apparatus with dry nitrogen. The uncertainty inherent in correction for the highly variable (with temperature) vapor pressure of ethyl ether was minimized by employing the relatively non-volatile amyl ether as solvent. Their data are included in the accompanying tabulation (references 1, 4, and 8).

Zerewitinoff, whose systematic investigations have resulted in the attachment of his name to this method, also adopted the Lunge nitrometer as a measuring instrument, and employed amyl ether as the Grignard reagent solvent. He added the refinement of using dry pyridine, a much more

¹Tissier and Grignard, *Compt. rend.*, 132, 835-7 (1901); *J. Chem. Soc.*, 80, 1, 316 (1901).

²Tschugaeff, *Ber.*, 35, 3912-4 (1902).

³Zerewitinoff, *Ber.*, 47, 1659 (1914).

⁴Hibbert and Sudborough, *Proc. Chem. Soc.*, 19, 285-6 (1903); *J. Chem. Soc.*, 85, 933-8 (1904).

nearly universal solvent than amyl ether, to dissolve the substances to be tested. Because his reaction chamber was small, and there was opportunity for oxygen absorption before mixture of the reactants, he regarded the use of an inert atmosphere as unnecessary. He did, however, make provision for careful temperature control. His apparatus and method are described in detail (with drawings) in the *Berichte*⁵ and in the *Zeitschrift für analytische Chemie*.⁶ The apparatus and method (with slight modifications) are also described in detail in the twenty-second edition of Gatterman-Wieland.⁷ In this form the method is well adapted to samples of the order of magnitude of 0.1 to 0.2 g.

Arnold and Rondestvedt⁸ (Table XVIII-I, reference 38) used a semi-micro modification of the Zerewitinoff apparatus, devised by Lauer and Zaugg, for samples of the order of magnitude of 80-100 mg., and stated that a description thereof was then "in press." Search of the *Chemical Abstracts* indices for 1946-51, however, fails to reveal any reference thereto. A micro apparatus suitable for use with samples of the order of magnitude of 3-10 mg. is described (with drawing) by Flaschenträger.⁹

In a modification of the method not described in great detail, Moureu and Mignonac¹⁰ used ethyl ether as solvent for both Grignard reagent and substance tested. Similar determinations have been made by Ciusa¹¹ and by Gilman and Fothergill.¹² A method of this kind, employing an atmosphere of nitrogen, and adapted to samples of the order of magnitude of 50-200 mg., is described (with drawing) by Braude and Stern.¹³ It is said to be accurate to $\pm 1-2$ percent, but is applicable only to relatively non-volatile compounds with functional groups reacting completely at room temperature. Correction for ether vapor is made from the vapor-pressure data of Taylor and Smith.¹⁴

Fuchs *et al.*¹⁵ describe (with diagram) a modified Zerewitinoff apparatus including a dibutyl phthalate manometer, and a procedure employing a *n*-butyl ether solution of methylmagnesium iodide under an atmosphere of nitrogen. After nitrogen flushing at 70°, the system is cooled to the vicinity of room temperature and maintained by means of a bath within a temperature range of 1° while reaction takes place. Results are calculated on the basis of the density of methane and the vapor pressure of *n*-butyl

⁵Zerewitinoff, *Ber.*, 40, 2023-31 (1907).

⁶Zerewitinoff, *Z. anal. Chem.*, 50, 680-91 (1911).

⁷English translation by W. McCartney, "Laboratory Methods of Organic Chemistry," The Macmillan Company, New York, 1934, pp. 72-4.

⁸Arnold and Rondestvedt, *J. Am. Chem. Soc.*, 68, 2176-8 (1946).

⁹Flaschenträger, *Z. physiol. Chem.*, 146, 219-26 (1925); *Chem. Abstr.*, 19, 3230 (1925).

¹⁰Moureu and Mignonac, *Compt. rend.*, 158, 1624-31 (1914).

¹¹Ciusa, *Gazz. chim. ital.*, 50, 11, 53-5 (1920); *Chem. Abstr.*, 15, 837 (1921).

¹²Gilman and Fothergill, *J. Am. Chem. Soc.*, 49, 2815-8 (1927).

¹³Braude and Stern, *J. Chem. Soc.*, 1946, 404-6.

¹⁴Taylor and Smith, *J. Am. Chem. Soc.*, 44, 2450-63 (1922).

¹⁵Fuchs, Ishler, and Sandhoff, *Ind. Eng. Chem., Anal. Ed.*, 12, 507-9 (1940).

ether at the temperature employed. The use of isoamyl ether is said to give results of equal precision but to require longer reaction times.

A somewhat similar apparatus in which, however, the reaction chamber and the gas burette are water-jacketed, is described (with diagram) by Lehman and Basch.¹⁶ Modification of the procedure to employ a pyridine suspension of methylmagnesium iodide-pyridine complex as the reagent, and methane saturated with pyridine vapor as the inert atmosphere, together with provision for the application of heat during the reaction period, leads to theoretical "active" hydrogen values for some compounds (such as picric acid and hydroquinone) that give negative results by the method of Fuchs *et al.*

Various other minor modifications of apparatus and method have been suggested or used from time to time (see, *e.g.*, Schmitz-Dumont and Hamann¹⁷; Oddo¹⁸). One of the more radical, though not necessarily more meritorious, innovations consists in operation under an atmosphere of carbon dioxide (Terent'ev *et al.*¹⁹). "The carbon dioxide enters the reaction vessel (after complete air replacement) under a layer of ethereal solution of the substance to be analyzed, to eliminate any initial reaction between carbon dioxide and methylmagnesium iodide. The stream of carbon dioxide is now broken. The methane formed replaces the carbon dioxide from the vessel and the reaction is completed in an atmosphere of methane. Dry carbon dioxide, which is now passed through, carries over the methane into the azotometer and reacts with excess of methylmagnesium iodide. By transferring the gas from the azotometer into the eudiometer it is measured, as is often done in Duma's nitrogen determination."

Although methylmagnesium iodide was used by Zerewitinoff and most of his followers, the bromide and chloride are equally applicable. For substances containing only "active" hydrogen groups the ethylmagnesium halides are just as satisfactory, but when reducible carbonyl groups are present the results may be complicated by ethylene evolution.

The substance to be analyzed may be treated as such, but more satisfactory results are usually obtained when it is dissolved in the Grignard reagent solvent, in pyridine, or in an aromatic hydrocarbon such as benzene, toluene, or xylene. Anisole and phenetole are also applicable as solvents, but necessitate a correction for the solubility of methane (Sudborough and Hibbert²⁰).

¹⁶Lehman and Basch, *Ind. Eng. Chem., Anal. Ed.*, 17, 428-9 (1945).

¹⁷Schmitz-Dumont and Hamann, *Ber.*, 66B, 71-6 (1933); *J. prakt. Chem.*, [2], 139, 162-6, 167-79 (1934).

¹⁸Oddo, *Ber.*, 44, 2048-52 (1911).

¹⁹Terent'ev and Shcherbakova, *J. Gen. Chem.* (U.S.S.R.), 10, 2041-6 (1940); 15, 86-9 (1945); 16, 855-8 (1946); Terent'ev, Shcherbakova, and Kremenskaya, *ibid.*, 17, 100-4 (1947); *Chem. Abstr.*, 35, 4308 (1941); 40, 1420 (1946); 41, 1575 (1947); 42, 109 (1948).

²⁰Sudborough and Hibbert, *J. Chem. Soc.*, 95, 477-80 (1909).

THE "GRIGNARD MACHINE"

For simultaneous estimations of the "active" hydrogen and the additive capacity of bifunctional compounds, Kohler²¹ devised an apparatus commonly known as the "Grignard machine." It and the method of operation are described in detail (with drawings) in the papers cited. Kohler operated under an atmosphere of nitrogen, purified by passage through a Fieser²² train. According to Hollyday and Cottle,²³ who describe (with drawing) a modified "Grignard machine," tank nitrogen constitutes an altogether satisfactory atmosphere for determinations of this kind.

By Kohler's method a measured volume of standardized methylmagnesium iodide-isoamyl ether solution (in considerable excess) is added to a 0.2-g. sample of the substance investigated (or to a xylene solution thereof). Reaction is facilitated by brief warming of the reaction mixture. The volume of evolved methane is then measured. The amount of unused Grignard reagent is then determined by the addition of a measured volume of water (in excess), and measurement of the volume of methane consequently evolved.

Substantially the original apparatus and method of Kohler have been employed by Smith and Guss,²⁴ by Whitmore *et al.*,²⁵ and by Kadesch²⁶ to study the competitive enolization and addition reactions of enolizable ketones. Their data are summarized in Table VI-IX of the section on enolization of Chapter VI.

A modification of the Grignard machine suitable for use with samples of the order of 2-20 mg., and a procedure employing amyl ether as solvent under an atmosphere of nitrogen, are described by Soltys.²⁷

"ACTIVE" HYDROGEN GROUPS

Generally speaking, compounds of the following types may be expected to react more or less rapidly with methylmagnesium halides at room temperature to give approximately quantitative yields of methane: water of hydration (two equivalents); the mineral acid salts of nitrogen bases; carboxylic, sulfonic, sulfinic, and sulfenic acids; phenols, alcohols, and glycols; hydroperoxides; mercaptans; phosphines; primary amines (one equivalent); secondary aromatic amines; amides (one equivalent); imides; cyclic amines of the pyrrole and indole types*; monosubstituted acetylenes*;

²¹Kohler, Stone, and Fuson, *J. Am. Chem. Soc.*, 49, 3181-8 (1927); Kohler and Richtmyer, *ibid.*, 52, 3736-8 (1930).

²²Fieser, *J. Am. Chem. Soc.*, 46, 2639-47 (1924).

²³Hollyday and Cottle, *Ind. Eng. Chem., Anal. Ed.*, 14, 774-6 (1942).

²⁴Smith and Guss, *J. Am. Chem. Soc.*, 59, 804-6 (1937).

²⁵Whitmore and Randall, *J. Am. Chem. Soc.*, 64, 1242-6 (1942); Whitmore and Block, *ibid.*, 64, 1619-21 (1942); Whitmore and Lewis, *ibid.*, 64, 2964-6 (1942).

²⁶Kadesch, *J. Am. Chem. Soc.*, 66, 1207-13 (1944).

²⁷Soltys, *Mikrochem.*, 20, 107-25 (1936); *Chem. Abstr.*, 30, 5146 (1936).

* Concerning these and acetylene see section on Hydrogen Displacement Methods, Chapter II, pp. 66-86.

monosubstituted hydrazines (2 equivalents); α,α -disubstituted hydrazines (one equivalent); α,β -disubstituted hydrazines (two equivalents); oximes; phenylhydrazones (one equivalent); semicarbazones (two equivalents).

Secondary aliphatic amines, although they react very slowly at room temperature (Hibbert²⁸), yield one equivalent of methane on heating (70–125°). As a rule primary amines yield one equivalent of methane at room temperature and a second on heating, (Sudborough and Hibbert²⁹), as do amides* (Zerewitinoff³⁰). Some polyfunctional compounds do not yield the quantity of methane corresponding to all the supposedly "active" hydrogen atoms present even when heated, presumably because of the insolubility (and consequent unreactivity) of the products of partial reaction. This is true, for example, of urea and thiourea, each of which liberates two equivalents of methane in the cold, and three on heating (Zerewitinoff, *loc. cit.*³⁰). In general, diamines also yield two equivalents of methane in the cold, and three on heating (Zerewitinoff³¹).

A few hydrocarbons, such as fluorene and its derivatives, indene (Zerewitinoff, *loc. cit.*³¹), pentadeca-6,9-diyne (Tchao Yin Lai³²), 1,5-diphenyl-1,4-pentadiyne, and 1-phenylpent-4-en-1-yne (Grignard and Lepayre³³), liberate methane when heated with methyl Grignard reagents.

The reactions of Grignard reagents with enolizable ketones are discussed in the section on enolization of Chapter VI, and the "Grignard machine" data of several investigators are recorded in Table VI-IX. When the ketone is strongly "hindered" so that the competitive addition reaction is completely circumvented, as in the case of acetomesitylene, the liberation of methane is approximately quantitative (Kohler *et al.*³⁴). According to Schlenk *et al.*,³⁵ the second "active" hydrogen of phenylacetic acid should also be attributed to enolization. Malonic ester (Zerewitinoff³⁶) undoubtedly falls in the same class.

Other "pseudo-acidic" substances react with methyl Grignard reagents to liberate methane in varying quantities. By way of example may be cited the nitriles with labile *alpha* hydrogen atoms, discussed in the section on Keteniminate Formation, Chapter X.

Ishikawa and Kojima³⁷ report a considerable degree of keteniminization of benzyl cyanide, and state further that, in pyridine solution, any anhydride,

²⁸Hibbert, *J. Chem. Soc.*, 101, 328–41 (1912).

²⁹Sudborough and Hibbert, *J. Chem. Soc.*, 95, 477–80 (1909).

*Trichloroacetamide is an exception, yielding two equivalents of methane in the cold.

³⁰Zerewitinoff, *Ber.*, 41, 2233–43 (1908).

³¹Zerewitinoff, *Ber.*, 45, 2384–9 (1912).

³²Tchao Yin Lai, *Bull. soc. chim.*, [4], 53, 1537–43 (1933).

³³Grignard and Lepayre, *Compt. rend.*, 192, 250–3 (1931); *Chem. Abstr.*, 25, 2421 (1931); *Bull. soc. chim.*, [4], 43, 930–1 (1928).

³⁴Kohler, Stone, and Fuson, *J. Am. Chem. Soc.*, 49, 3181–8 (1927).

³⁵Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135–54 (1931).

³⁶Zerewitinoff, *Ber.*, 41, 2233–43 (1908).

³⁷Ishikawa and Kojima, *Science Repts. Tokyo Bunsika Daigaku*, 1, 289–96 (1934); *Chem. Abstr.*, 28, 2697 (1934).

such as acetic, butyric, isovaleric, succinic, or phenylacetic, which contains neighboring carboxyl, methyl, or methylene groups invariably has an "active" hydrogen content varying from 1.21 for phenylacetic to 0.14 for isovaleric.

It has sometimes been assumed³⁸ that the reactions of aliphatic nitro compounds with Grignard reagents are essentially reactions of the *aci* forms. That this can scarcely be taken for granted, however, is indicated by the gas-forming reactions with methyl Grignard reagents of aromatic nitro compounds³⁹ and such non-hydrogenous aliphatic nitro compounds as tribromo- and trichloronitromethane⁴⁰ and tetranitromethane.⁴¹

Sulfones with labile *alpha* hydrogen atoms also undergo a reaction analogous to enolate formation.^{41,1} For example, phenethyl *p*-tolyl sulfone and β,β -diphenylethyl *p*-tolyl sulfone each liberate at least one molecular equivalent of methane when treated with methylmagnesium iodide at 50–75°. Methyl *p*-tolyl sulfone (with methylmagnesium iodide) liberates methane slowly at room temperature; when heated it appears to have two "active" hydrogen atoms.

SOURCES OF ERROR, AND LIMITATIONS OF THE METHOD

Aside from the foregoing discussion, the reader's general knowledge of the properties of Grignard reagents would suggest the advisability of precautions to exclude moisture and oxygen. As has already been mentioned, the use of anisole or phenetole as solvents necessitates correction for the solubility of methane (Sudborough and Hibbert⁴²). Some investigators have encountered errors in the use of pyridine as a sample solvent. Schmitz-Dumont and Hamann,⁴³ for example, found it desirable to introduce into their determinations corrections based on blank runs. Tanberg⁴⁴ reported considerable gas evolution upon the addition of various samples of pyridine to methylmagnesium iodide solution, and concluded that pyridine is not a suitable solvent for "active" hydrogen determinations.

Zerewitinoff⁴⁵ suggested that one source of gas evolution in Tanberg's experiments might be the presence in the Grignard reagent of excess

³⁸See, e.g., Zerewitinoff, *Ber.*, 43, 3590–5 (1910).

³⁹Gilman and Fothergill, *J. Am. Chem. Soc.*, 49, 2815–8 (1927); see also the section on Nitro Compounds, Chapter XIX.

⁴⁰Gilman and Fothergill, *Bull. soc. chim.*, [4], 45, 1132–6 (1929).

⁴¹Gilman, Fothergill, and Towne, *J. Am. Chem. Soc.*, 52, 405–7 (1930).

^{41,1}Kohler and Potter, *J. Am. Chem. Soc.*, 57, 1316–21 (1935); *ibid.*, 58, 2166–70 (1936); Gilman and Webb, *ibid.*, 71, 4062–6 (1949); Field, *ibid.*, 74, 3919–21 (1952).

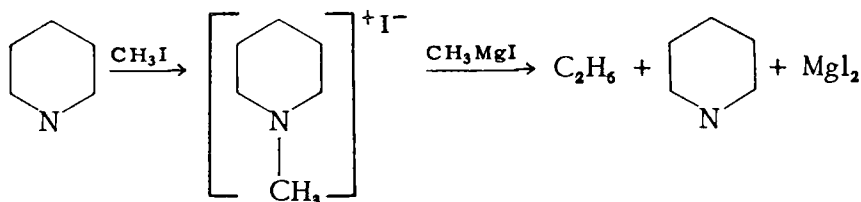
⁴²Sudborough and Hibbert, *J. Chem. Soc.*, 95, 477–80 (1907).

⁴³Schmitz-Dumont and Hamann, *J. prakt. Chem.*, [2], 139, 162–6 (1934).

⁴⁴Tanberg, *J. Am. Chem. Soc.*, 36, 335–7 (1914).

⁴⁵Zerewitinoff, *Ber.*, 47, 2417–23 (1914).

methyl iodide, giving rise to the reaction sequence



(See section on Quaternary Salts, Chapter XIX.) He further called attention to the fact that Tanberg's pyridine was dried by twenty-four hour reflux with barium oxide, and showed experimentally that pyridine undergoes reduction upon prolonged heating with barium hydroxide.

Jurecek⁴⁶ also calls attention to precautions to be observed in the use of pyridine as a sample solvent. When pyridine is used as a suspending medium for the Grignard reagent-pyridine complex as well as for a sample solvent, the solubility of methane in pyridine must also be taken into account (Lehman and Basch⁴⁷).

Hibbert⁴⁸ reported that primary aliphatic alcohols, especially the lower members of the series, give results materially lower than the theoretical when measured for "active" hydrogen by his variation of Tschugaeff's method. Zerewitinoff's⁴⁹ determinations reveal no such error. Hollyday and Cottle⁵⁰ have discovered one source of this discrepancy in the respective concentrations employed by the two investigators. Check experiments showed that methanol at a concentration of 0.245 mole per liter of the reaction mixture liberated 89 percent of the theoretical quantity of methane; at 0.100 molar, 94 percent; and at 0.0647 molar, 99.9 percent. Apparently the methoxide precipitate formed at relatively high concentrations carries with it some methanol of solvation. Another probable source of error in Hibbert's determinations is the loss of relatively volatile test material in the course of sweeping the apparatus with nitrogen.

Variations in apparent "active" hydrogen values with solvent employed have been investigated by Lieff *et al.*⁵¹ Their data are included in Table XVIII-I (reference 27). In general, the discrepancies between values obtained in the solvents commonly used (provided the media are truly *solvents* for the materials tested) are relatively trivial; dioxane, however, is an exception insofar as samples containing enolizable carbonyl groups are concerned. Wright⁵² has related this phenomenon to the relative reactivities of dimethylmagnesium and the ordinary methyl Grignard reagent with respect to carbonyl-group addition. Dimethylmagnesium being the less reactive with respect to carbonyl-group addition tends to give some-

⁴⁶Jureček, *Chem. Listy*, 40, 239-45 (1946); *Chem. Abstr.*, 44, 9220 (1950).

⁴⁷Lehman and Basch, *Ind. Eng. Chem., Anal. Ed.*, 17, 428-9 (1945).

⁴⁸Hibbert, *J. Chem. Soc.*, 101, 328-41 (1912).

⁴⁹Zerewitinoff, *Ber.*, 40, 2023-31 (1907); 45, 2384-9 (1912).

⁵⁰Hollyday and Cottle, *Ind. Eng. Chem., Anal. Ed.*, 14, 774-6 (1942).

⁵¹Lieff, Wright, and Hibbert, *J. Am. Chem. Soc.*, 61, 865-7 (1939).

⁵²Wright, *J. Am. Chem. Soc.*, 61, 1152-6 (1939).

what higher "active" hydrogen values when compounds containing enolizable carbonyl groups are tested in dioxane.

It has been found by Fuchs *et al.*⁵³ that certain polyfunctional phenols (e.g., hydroquinone, toluhydroquinone, phloroglucinol) and certain polyfunctional aromatic acids (e.g., phthalic, isophthalic, terephthalic, trimesic, pyromellitic) do not react with methylmagnesium iodide in *n*-butyl ether solution at or near room temperature. As has been suggested by Lehman and Basch,⁵⁴ this is probably a consequence of the relative insolubilities of these compounds and of their initial reaction products in the medium chosen. In warm pyridine these compounds all react with methylmagnesium iodide, and most of them liberate methane equivalent to the calculated number of "active" hydrogen atoms present.

Other sources of error are to be found chiefly in gas-forming reactions of "interfering" groups. Readily reducible carbonyl groups, for example, may react with aliphatic Grignard reagents other than the methyl to liberate olefins (see section on Grignard Reductions in Chapter VI). The reactions of nitro groups, already mentioned in the foregoing discussion, have been investigated, albeit not very exhaustively, by Gilman *et al.*⁵⁵ Nitroso, azoxy, and azo compounds also undergo gas-forming reactions with methyl Grignard reagents (see sections on these various types of compounds in Chapter XIX on Miscellaneous Nitrogen Compounds).

APPLICATIONS OF THE METHOD

Applications of the method to the study of simultaneous addition, enolization, and reduction reactions of ketones have already been mentioned, and are discussed in Chapter VI. Zerewitinoff has used it for the estimation of water in anthracite⁵⁶ and of free fatty acids in natural oils.⁵⁷ Allen *et al.*,⁵⁸ have employed it to distinguish between lactols and open-chain ketonic acids. Greenwood and Gortner⁵⁹ have investigated the supposed "protection" of amino groups by hydrochloride formation, using a procedure that is essentially a modified Zerewitinoff determination. Wright⁶⁰ has studied the relative reactivities of methylmagnesium chloride and dimethylmagnesium with respect to "active" hydrogen groups and carbonyl-group addition. By a special adaptation of the Zerewitinoff method, Ivanoff *et al.* have studied the rates of gas evolution in the reac-

⁵³Fuchs, Ishler and Sandhoff, *Ind. Eng. Chem., Anal. Ed.*, 12, 507-9 (1940).

⁵⁴Lehman and Basch, *Ind. Eng. Chem., Anal. Ed.*, 17, 428-9 (1945).

⁵⁵Gilman and Fothergill, *J. Am. Chem. Soc.*, 49, 2815-8 (1927); *Bull. soc. chim.*, [4], 45, 1132-6 (1929); Gilman, Fothergill, and Towne, *J. Am. Chem. Soc.*, 52, 405-7 (1930).

⁵⁶Zerewitinoff, *Z. anal. Chem.*, 50, 680-91 (1911).

⁵⁷Zerewitinoff, *Z. anal. Chem.*, 52, 729-37 (1914).

⁵⁸Allen, Normington, and Wilson, *Can. J. Research*, 11, 382-94 (1934); *Chem. Abstr.*, 29, 135 (1935).

⁵⁹Greenwood and Gortner, *J. Org. Chem.*, 6, 401-9 (1941).

⁶⁰Wright, *J. Am. Chem. Soc.*, 61, 1152-6 (1939).

tions of various aliphatic Grignard reagents with chloromagnesium phenylacetate⁶¹ and indene⁶² in the erroneous belief that they could thus establish a relative order of bond forces in a series of molecules of the type R—MgX. Innumerable investigators have, of course, used the method in attempts to arrive at satisfactory constitutional assignments for substances of unknown structure.

Hibbert⁶³ has used the amounts of methane evolved in reactions of methylmagnesium iodide with a series of α -naphthol-ketone mixtures to estimate roughly the relative reactivities of the ketones. Lewis and Wright⁶⁴ have adopted essentially the same method to compare the reactivity of benzophenone with those of various *para*-substituted benzophenones.

A representative, though not exhaustive collection of data is presented in Table XVIII-I. Data relating to substances of indefinite, uncertain, or unknown constitution are purposely omitted, as are studies of substances of highly complicated structure, such as that of Fischer and Rothmund⁶⁵ on hæmin and pyrrole derivatives.

⁶¹Ivanoff and Spassoff, *Bull. soc. chim.*, [4], 51, 619-22 (1932).

⁶²Ivanoff and Abdouloff, *Compt. rend.*, 196, 491-3 (1933); *Chem. Abstr.*, 27, 2421 (1933); Ivanov and Ibdulov, *Ann. univ. Sofia II, Faculté phys.-math.*, 30, 53-8 (1934); *Chem. Abstr.*, 29, 2951 (1935).

⁶³Hibbert, *J. Chem. Soc.*, 101, 341-5 (1912).

⁶⁴Lewis and Wright, *J. Am. Chem. Soc.*, 74, 1257-9 (1952).

⁶⁵Fischer and Rothmund, *Ber.*, 61B, 1268-76 (1928).

TABLE XVIII-I

RESULTS OF DETERMINATIONS OF APPARENT "ACTIVE" HYDROGEN CONTENT BY
THE TSCHUGAEFF-ZEREWITINOFF METHOD

Grignard reagents used (G.R.) are indicated as follows: (Me), CH_3MgI ; (Me^*), CH_3MgBr ; (Me^\dagger), CH_3MgCl ; (Me^\ddagger), $(\text{CH}_3)_2\text{Mg}$; (Et), $\text{C}_2\text{H}_5\text{MgI}$; (Et^*), $\text{C}_2\text{H}_5\text{MgBr}$; (Et^\dagger), $\text{C}_2\text{H}_5\text{MgCl}$; (Pr^*), $n\text{-C}_3\text{H}_7\text{MgBr}$; (Bu^*), $n\text{-C}_4\text{H}_9\text{MgBr}$.

	Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
				Cold	Heated	
C₁						
	Br_3CNO_2 (Me)	Bu_2O	Bu_2O	—	0.95	21
	Cl_3CNO_2 (Me)	$i\text{-Am}_2\text{O}$	$i\text{-Am}_2\text{O}$	—	0.43	21
	$(\text{O}_2\text{N})_4\text{C}$ (Me)	Bu_2O	Bu_2O	—	0.99	22
	CH_3NO_2 (Me)	Am_2O	Am_2O	0.83	0.93	6
	CH_3NO_2 (Me)	Am_2O	$\text{C}_5\text{H}_5\text{N}$	0.97	—	6
	CH_3NO_2 (Et^*)	Et_2O	Et_2O	0.87	—	13
	$(\text{H}_2\text{N})_2\text{CS}$ (Me)	Am_2O	$\text{C}_5\text{H}_5\text{N}$	2.14	2.77	3
	CH_3OH (Me)	EtOPh	EtOPh	0.44	—	8
	CH_3OH (Me)	Am_2O	$\text{C}_5\text{H}_5\text{N}$	0.96	—	9
	CH_3OH (Me)	$i\text{-Am}_2\text{O}$	$i\text{-Am}_2\text{O}$	0.82–0.97	0.89–1.03	41
	CH_3OH (Et^*)	Et_2O	Et_2O	1.07	—	13
	$(\text{H}_2\text{N})_2\text{CO}$ (Me)	Am_2O	$\text{C}_5\text{H}_5\text{N}$	2.15	3.09	3
C₂						
	$\text{Cl}_3\text{CCONH}_2$ (Me)	Am_2O	$\text{C}_5\text{H}_5\text{N}$	2.05	—	3
	$\text{Cl}_3\text{CCHO}\cdot\text{H}_2\text{O}$ (Me)	Am_2O	Am_2O	2.04	—	1
	CH_3COSH (Et)	$i\text{-Am}_2\text{O}$	$\text{C}_5\text{H}_5\text{N}$	0.77	—	7
	$\text{CH}_3\text{CO}_2\text{H}$ (Et)	$i\text{-Am}_2\text{O}$	$\text{C}_5\text{H}_5\text{N}$	0.81	—	7
	CH_3CSNH_2 (Me)	Am_2O	$\text{C}_5\text{H}_5\text{N}$	1.26	2.08	3
	CH_3CONH_2 (Me)	Am_2O	$\text{C}_5\text{H}_5\text{N}$	1.04	2.11	3
	$\text{C}_2\text{H}_5\text{NO}_2$ (Me)	Am_2O	Am_2O	0.65	0.79	6
	$\text{C}_2\text{H}_5\text{NO}_2$ (Et^*)	Et_2O	Et_2O	0.95	—	13
	$\text{C}_2\text{H}_5\text{OH}$ (Me)	EtOPh	EtOPh	0.72	—	8

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₂ (cont.)					
C ₂ H ₅ OH (Me)	Am ₂ O	C ₅ H ₅ N	1.03	—	9
C ₂ H ₅ OH (Me)	<i>i</i> -Am ₂ O	<i>i</i> -Am ₂ O	—	0.99-1.02	41
C ₂ H ₅ OH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	1.03	—	7
(—CH ₂ OH) ₂ (Me)	Am ₂ O	C ₅ H ₅ N	2.04	—	2
(—CH ₂ OH) ₂ (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	2.02	—	7
CH ₃ CH(NH ₂)OH (Me)	Am ₂ O	C ₅ H ₅ N	2.10	3.08	3
(—CH ₂ NH ₂) ₂ (Me)	Am ₂ O	C ₅ H ₅ N	1.80	2.77	9
C₃					
C ₃ HCl ₇ (Me)	Et ₂ O	Et ₂ O	<i>ca.</i> 1	—	47
H ₂ C(CO ₂ H) ₂ (Me)	Am ₂ O	C ₅ H ₅ N	2.86	—	3
H ₂ C=CHCH ₂ OH (Me)	<i>i</i> -Am ₂ O	<i>i</i> -Am ₂ O	—	1.00	41
H ₂ C=CHCH ₂ OH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.91	—	7
H ₂ C(CONH ₂) ₂ (Me)	Am ₂ O	C ₅ H ₅ N	2.25	4.23	3
(CH ₃) ₂ C=NOH (Me)	Am ₂ O	Am ₂ O	0.99	—	1
<i>n</i> -C ₃ H ₇ NO ₂ (Me)	Am ₂ O	Am ₂ O	0.68	0.71	6
<i>i</i> -C ₃ H ₇ NO ₂ (Me)	Am ₂ O	Am ₂ O	0.69	0.81	6
H ₂ NCO ₂ C ₂ H ₅ (Me)	Am ₂ O	C ₅ H ₅ N	2.04	—	10
H ₂ NCO ₂ C ₂ H ₅ (Me)	Am ₂ O	C ₅ H ₅ N	1.19	1.89	3
H ₂ NCO ₂ C ₂ H ₅ (Me)	Am ₂ O	Am ₂ O	1.22	2.00	3
<i>n</i> -C ₃ H ₇ SH (Me)	Am ₂ O	C ₅ H ₅ N	0.93	—	3
<i>n</i> -C ₃ H ₇ OH (Me)	EtOPh	EtOPh	0.83	—	8
<i>n</i> -C ₃ H ₇ OH (Me)	Am ₂ O	C ₅ H ₅ N	1.05	—	9
<i>n</i> -C ₃ H ₇ OH (Me)	<i>i</i> -Am ₂ O	<i>i</i> -Am ₂ O	—	1.00	41
<i>n</i> -C ₃ H ₇ OH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.98	—	7
CH ₃ CH(OH)CH ₂ OH (Me)	Am ₂ O	C ₅ H ₅ N	1.96	—	2
CH ₃ CH(OH)CH ₂ OH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	2.01	—	7

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₃ (<i>cont.</i>)					
<i>n</i> -C ₃ H ₇ NH ₂ (Et*)	Et ₂ O	Et ₂ O	1.04	—	11
C₄					
Pyrrole (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.99	—	7
Pyrrole (Et*)	Et ₂ O	Et ₂ O	1.00	—	13
Succinimide (Me)	Am ₂ O	C ₅ H ₅ N	1.14	—	3
Succinimide (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.95	—	7
(HO ₂ CCH ₂ —) ₂ (Me)	Am ₂ O	C ₅ H ₅ N	2.04	—	2
[HO ₂ CCH(OH)—] ₂ (Me)	Am ₂ O	C ₅ H ₅ N	4.02	—	2
H ₅ C ₂ O ₂ CCONH ₂ (Me)	Am ₂ O	C ₅ H ₅ N	1.24	1.93	3
<i>n</i> -C ₃ H ₇ CO ₂ H (Me)	Am ₂ O	C ₅ H ₅ N	1.02	—	12
<i>n</i> -C ₃ H ₇ CO ₂ H (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.94	—	7
α-[HON=C(CH ₃)—] ₂	Am ₂ O	C ₅ H ₅ N	2.04	—	2
4-Hydroxymethyl-1,3-dioxolane (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	1.09	27
4-Hydroxymethyl-1,3-dioxolane (Me)	<i>i</i> -Am ₂ O	Dioxane	—	1.06	27
<i>i</i> -C ₄ H ₉ SH (Me)	Am ₂ O	C ₅ H ₅ N	0.98	—	3
<i>i</i> -C ₄ H ₉ OH (Me)	Am ₂ O	C ₅ H ₅ N	1.00	—	9
<i>t</i> -C ₄ H ₉ OH (Me)	<i>i</i> -Am ₂ O	<i>i</i> -Am ₂ O	—	1.01	41
HOCH ₂ (CHOH) ₂ CH ₂ OH (Me)	Am ₂ O	C ₅ H ₅ N	4.06	—	2
HOCH ₂ (CHOH) ₂ CH ₂ OH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	3.81	—	7
(C ₂ H ₅) ₂ NH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.98	—	7
(C ₂ H ₅) ₂ NH (Et*)	Et ₂ O	Et ₂ O	1.05	—	11
<i>n</i> -C ₄ H ₉ NH ₂ (Et*)	Et ₂ O	Et ₂ O	1.03	—	11
C₅					
1-Methylpyrrole (Et*)	Et ₂ O	Et ₂ O	0.00	—	13
Glutarimide (Me)	Am ₂ O	C ₅ H ₅ N	1.03	—	3

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₅ (cont.)					
(CH ₃ CO) ₂ CH ₂ (Me)	Am ₂ O	Am ₂ O	0.82	1.00	3
(CH ₃) ₂ C(CO ₂ H) ₂ (Me)	Am ₂ O	C ₅ H ₅ N	2.02	—	2
CH ₃ CH(OH)CO ₂ C ₂ H ₅ (Me)	Am ₂ O	C ₅ H ₅ N	1.06	—	2
Arabinose (Me)	Am ₂ O	C ₅ H ₅ N	4.01	—	2
(CH ₂) ₅ NH (Et*)	Et ₂ O	Et ₂ O	1.05	—	11
3-Methylpyrrolidine (Et*)	Et ₂ O	Et ₂ O	1.07	—	11
<i>i</i> -C ₅ H ₁₁ SH (Me)	Am ₂ O	C ₅ H ₅ N	0.99	—	3
<i>i</i> -C ₅ H ₁₁ OH (Me)	Am ₂ O	C ₅ H ₅ N	0.97	—	2
<i>i</i> -C ₅ H ₁₁ OH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.93	—	7
<i>t</i> -C ₅ H ₁₁ OH (Me)	Am ₂ O	C ₅ H ₅ N	1.03	—	2
C(CH ₂ OH) ₄ (Me)	Am ₂ O	C ₅ H ₅ N	4.09	—	2
C₆					
Br ₃ C ₆ NO ₂ (Me)	Bu ₂ O	Bu ₂ O	—	1.43	22
1,3,4,5-Cl ₄ C ₆ (NO ₂) ₂ (Me)	Bu ₂ O	Bu ₂ O	—	1.96 ^a	21
1,3,4,5-Cl ₄ C ₆ (NO ₂) ₂ (Me [†])	Bu ₂ O	Bu ₂ O	—	2.24 ^b	21
2,4,6-Br ₃ C ₆ H ₂ OH (Me)	EtOPh	EtOPh	0.91	—	8
2,4,6-Br ₃ C ₆ H ₂ OH (Me)	Bu ₂ O	—	1.06	—	43
1,3,5-(O ₂ N) ₃ C ₆ H ₃ (Me)	Bu ₂ O	Xylene	2.51	3.47	20
1,3,5-(O ₂ N) ₃ C ₆ H ₃ (Et*)	Et ₂ O	Et ₂ O	0.00	—	13
1,3,5-(O ₂ N) ₃ C ₆ H ₃ (Et*)	Et ₂ O	Et ₂ O	—	1.49	16
2,4,6-(O ₂ N) ₃ C ₆ H ₂ OH (Me)	Bu ₂ O	—	0.00	—	43
2,4,6-(O ₂ N) ₃ C ₆ H ₂ OH (Me)	C ₅ H ₅ N	—	—	1.00	44
C ₆ H ₅ NO (Et*)	Et ₂ O	Et ₂ O	—	1.09	16

^a Heated at 70° for 1.50 hour.^b Heated at 70° for 1.00 hour.

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₆ (<i>cont.</i>)					
C ₆ H ₅ NO ₂ (Me)	Bu ₂ O	C ₅ H ₅ N	—	1.49	21
C ₆ H ₅ NO ₂ (Me)	Bu ₂ O	Bu ₂ O	—	1.13-1.57	21
C ₆ H ₅ NO ₂ (Me)	Et ₂ O	Et ₂ O	—	0.97	16
C ₆ H ₅ NO ₂ (Me)	Bu ₂ O	Bu ₂ O	0.98	1.03	16
C ₆ H ₅ NO ₂ (Et*)	Et ₂ O	Et ₂ O	—	1.53	16
C ₆ H ₅ NO ₂ (<i>n</i> -Pr*)	Et ₂ O	Et ₂ O	—	1.90	16
C ₆ H ₅ NO ₂ (<i>n</i> -Bu*)	Et ₂ O	Et ₂ O	—	1.68	16
2-O ₂ NC ₆ H ₄ OH (Me)	Am ₂ O	Am ₂ O	1.15	—	1
4-O ₂ NC ₆ H ₄ OH (Me)	Am ₂ O	MeOPh	0.89	—	6
4-ClC ₆ H ₄ NH ₂ (Me)	EtOPh	EtOPh	0.89	—	8
4-ClC ₆ H ₄ NH ₂ (Me)	EtOPh	EtOPh	0.99	1.95	4
C ₆ H ₅ SH (Me)	Am ₂ O	C ₅ H ₅ N	1.04	—	3
C ₆ H ₅ OH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	1.13	—	7
C ₆ H ₅ OH (Et*)	Et ₂ O	Et ₂ O	1.04	—	13
OC<(CH=CH) ₂ >CHOH (Me)	Am ₂ O	Am ₂ O	—	1.03	1
1,2-(HO) ₂ C ₆ H ₄ (Me)	Am ₂ O	C ₅ H ₅ N	1.93	—	2
1,2-(HO) ₂ C ₆ H ₄ (Me)	Bu ₂ O	—	1.99	—	43
1,3-(HO) ₂ C ₆ H ₄ (Me)	Am ₂ O	Am ₂ O	2.00	—	1
1,3-(HO) ₂ C ₆ H ₄ (Me)	Bu ₂ O	—	0.98	—	43
1,3-(HO) ₂ C ₆ H ₄ (Me)	C ₅ H ₅ N	—	—	0.96	44
1,3-(HO) ₂ C ₆ H ₄ (Et*)	Et ₂ O	Et ₂ O	2.01	—	13
1,3-(HO) ₂ C ₆ H ₄ (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	2.15	—	7
1,4-(HO) ₂ C ₆ H ₄ (Me)	Am ₂ O	C ₅ H ₅ N	2.02	—	2
1,4-(HO) ₂ C ₆ H ₄ (Me)	Bu ₂ O	—	0.00	—	43
1,4-(HO) ₂ C ₆ H ₄ (Me)	C ₅ H ₅ N	—	—	2.01	44
1,4-(HO) ₂ C ₆ H ₄ (Me†)	Et ₂ O	Et ₂ O	1.60	—	40
3-O ₂ NC ₆ H ₄ NH ₂ (Me)	Am ₂ O	MeOPh	1.02	1.80	6

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₆ (cont.)					
3-O ₂ NC ₆ H ₄ NH ₂ (Me)	Am ₂ O	Mesitylene	1.01	1.85	6
C ₆ H ₅ SO ₂ H (Me)	Am ₂ O	C ₅ H ₅ N	0.97	—	2
C ₆ H ₅ SO ₂ H (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.95	—	7
1,2,3-(HO) ₂ C ₆ H ₃ (Me)	Am ₂ O	Am ₂ O	3.00	—	1
1,2,3-(HO) ₃ C ₆ H ₃ (Me)	Bu ₂ O	—	3.02	—	43
1,2,3-(HO) ₃ C ₆ H ₃ (Me)	C ₅ H ₅ N	—	—	2.80	44
1,3,5-(HO) ₃ C ₆ H ₃ (Me)	Bu ₂ O	—	0.00	—	43
1,3,5-(HO) ₃ C ₆ H ₃ (Me)	C ₅ H ₅ N	—	—	1.00	44
C ₆ H ₅ NH ₂ (Me [†])	Et ₂ O	Et ₂ O	1.94	—	40
C ₆ H ₅ NH ₂ (Me [†])	Et ₂ O	C ₆ H ₆	1.00	—	40
C ₆ H ₅ NH ₂ (Et*)	Et ₂ O	Et ₂ O	1.03	—	11
C ₆ H ₅ PH ₂ (Et*)	Et ₂ O	Et ₂ O-C ₆ H ₆	—	<i>ca.</i> 2	18
C ₆ H ₅ NHNH ₂ (Et*)	Et ₂ O	Et ₂ O	1.96	—	11
1,2-(H ₂ N) ₂ C ₆ H ₄ (Me)	Am ₂ O	C ₅ H ₅ N	1.89	2.81	9
1,2-(H ₂ N) ₂ C ₆ H ₄ (Me)	Am ₂ O	MeOPh	2.24	3.09	9
1,3-(H ₂ N) ₂ C ₆ H ₄ (Me)	Am ₂ O	C ₅ H ₅ N	1.93	2.82	9
1,3-(H ₂ N) ₂ C ₆ H ₄ (Et*)	Et ₂ O	Et ₂ O	1.91	—	11
1,4-(H ₂ N) ₂ C ₆ H ₄ (Me)	Am ₂ O	C ₅ H ₅ N	1.90	2.91	9
CH ₃ COCH ₂ CO ₂ C ₂ H ₅ (Me)	Am ₂ O	C ₅ H ₅ N	0.87	—	3
CH ₃ COCH ₂ CO ₂ C ₂ H ₅ (Me)	Am ₂ O	Am ₂ O	0.95	1.14	3
CH ₃ COCH ₂ CO ₂ C ₂ H ₅ (Me)	Am ₂ O	Am ₂ O	0.93	—	1
CH ₃ COCH ₂ COC ₂ H ₅ (Me [†])	Et ₂ O	Et ₂ O	1.01	—	40
CH ₃ COCH ₂ CO ₂ C ₂ H ₅ (Et*)	Et ₂ O	Et ₂ O	1.05	—	13
Cyclohexene hydroperoxide (Me)	Am ₂ O	C ₅ H ₅ N	0.91	—	33
CH ₃ COCH ₂ CO ₂ C ₂ H ₅ (Me)	<i>i</i> -Am ₂ O	—	1.00	—	43
1,3,5-(HO) ₃ C ₆ H ₃ ·2H ₂ O (Me)	Am ₂ O	C ₅ H ₅ N	7.13	—	2
<i>n</i> -C ₅ H ₁₁ CO ₂ H (Me)	Am ₂ O	C ₅ H ₅ N	0.98	—	12

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₆ (<i>cont.</i>)					
(—CONHC ₂ H ₅) ₂ (Me)	Am ₂ O	C ₅ H ₅ N	2.19	—	3
Glucose (Me)	Am ₂ O	C ₅ H ₅ N	—	4.58	27
Glucose (Me)	Am ₂ O	Dioxane	—	1.10	27
(CH ₂) ₅ CHNH ₂ (Et*)	Et ₂ O	Et ₂ O	1.05	—	11
CH ₃ COCH ₂ CH ₂ NR ₂ (Me) (R = CH ₃ , C ₂ H ₅ , <i>n</i> -C ₄ H ₉)	<i>i</i> -Am ₂ O	—	0.90–0.95	—	35
Glucose (Me) (C ₆ H ₁₂ O ₆ ·H ₂ O)	Am ₂ O	C ₅ H ₅ N	6.69	—	2
Mannitol (Me)	Am ₂ O	C ₅ H ₅ N	6.02	—	2
Mannitol (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	5.82	—	7
<i>i</i> -C ₆ H ₁₃ NH ₂ (Et*)	Et ₂ O	Et ₂ O	1.00	—	11
Rhamnose (Me) (C ₆ H ₁₆ O ₅ ·H ₂ O)	Am ₂ O	C ₅ H ₅ N	5.93	—	2
C₇					
2-O ₂ NC ₆ H ₄ CHO (Me)	Am ₂ O	C ₅ H ₅ N	1.00	—	15
2-O ₂ NC ₆ H ₄ CHO (Et*)	Et ₂ O	Et ₂ O	—	1.67	16
3-O ₂ NC ₆ H ₄ CHO (Me)	Am ₂ O	C ₅ H ₅ N	0.21	—	15
3-O ₂ NC ₆ H ₄ CHO (Et*)	Et ₂ O	Et ₂ O	—	1.43	16
4-O ₂ NC ₆ H ₄ CHO (Me)	Am ₂ O	C ₅ H ₅ N	0.29	—	15
2,4-(O ₂ N) ₂ C ₆ H ₄ CHO (Me)	Am ₂ O	C ₅ H ₅ N	1.03	—	15
C ₆ H ₅ CO ₂ H (Me)	Et ₂ O	Et ₂ O	—	0.96	16
C ₆ H ₅ CO ₂ H (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	1.18	27
C ₆ H ₅ CO ₂ H (Me)	<i>i</i> -Am ₂ O	Dioxane	—	1.06	27
C ₆ H ₅ CO ₂ H (Me)	Bu ₂ O	—	1.02	—	43
C ₆ H ₅ CO ₂ H (Me)	Bu ₂ O	Xylene	1.03	1.15	20
C ₆ H ₅ CO ₂ H (Et*)	Et ₂ O	Et ₂ O	—	1.01	16
2-HOC ₆ H ₄ CO ₂ H (Me)	Am ₂ O	C ₅ H ₅ N	2.04	—	2
2-HOC ₆ H ₄ CO ₂ H (Me†)	Et ₂ O	C ₆ H ₆	2.00	—	40
2-HOC ₆ H ₄ CO ₂ H (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	1.94	—	7

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₇ (cont.)					
C ₆ H ₅ CONH ₂ (Me)	Am ₂ O	C ₅ H ₅ N	0.97	2.16	3
C ₆ H ₅ CH ₂ NO ₂ (Me)	Am ₂ O	C ₅ H ₅ N	0.75	—	6
2-CH ₃ C ₆ H ₄ NO ₂ (Me)	Bu ₂ O	Bu ₂ O	—	1.20-1.36 ^c	21
2-H ₂ NC ₆ H ₄ CO ₂ H (Me)	Bu ₂ O	Xylene	2.50	3.54	20
C ₆ H ₅ CH ₂ SH (Me)	Am ₂ O	C ₅ H ₅ N	0.95	—	3
C ₆ H ₅ NHCSNH ₂ (Me)	Am ₂ O	C ₅ H ₅ N	1.93	2.21	3
C ₆ H ₅ CH ₂ OH (Me)	EtOPh	EtOPh	0.84	—	8
C ₆ H ₅ CH ₂ OH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	1.00	—	7
C ₆ H ₅ NHCONH ₂ (Me)	Am ₂ O	C ₅ H ₅ N	1.85	2.02	3
2-CH ₃ OC ₆ H ₄ OH (Me)	Am ₂ O	C ₅ H ₅ N	1.05	—	2
2-CH ₃ OC ₆ H ₄ OH (Me)	Am ₂ O	C ₅ H ₅ N	1.04	—	14
1,4-(HO) ₂ -2-CH ₃ C ₆ H ₃ (Me)	Bu ₂ O	—	0.00	—	43
2-CH ₃ C ₆ H ₅ NO ₂ (Et*)	Et ₂ O	Et ₂ O	—	1.69	16
4-CH ₃ C ₆ H ₅ NO ₂ (Et*)	Et ₂ O	Et ₂ O	—	1.65	16
"Methoxyresorcinol" (Me)	Bu ₂ O	—	2.07	—	43
CH ₃ NHC ₆ H ₅ (Me)	EtOPh	EtOPh	1.00	—	4
CH ₃ NHC ₆ H ₅ (Et*)	Et ₂ O	Et ₂ O	1.03	—	11
2-CH ₃ C ₆ H ₄ NH ₂ (Me)	Am ₂ O	C ₅ H ₅ N	1.89	2.93	9
4-CH ₃ C ₆ H ₄ NH ₂ (Me)	Am ₂ O	Am ₂ O	0.98	1.95	4
C ₆ H ₅ CH ₂ NH ₂ (Et*)	Et ₂ O	Et ₂ O	0.96	—	11
4-CH ₃ OC ₆ H ₄ NH ₂ (Et*)	Et ₂ O	Et ₂ O	1.07	—	11
Methylketol (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.97	—	7
H ₂ C(CO ₂ C ₂ H ₅) ₂ (Me)	Bu ₂ O	—	1.00	—	43
H ₂ C(CO ₂ C ₂ H ₅) ₂ (Me)	Am ₂ O	C ₅ H ₅ N	1.03	—	3
α-Methylglucoside (Me)	Am ₂ O	C ₅ H ₅ N	4.09	—	2

^c Heated at 70° for 0.50 to 1.50 hour.

TABLE XVIII-I (Continued)

	Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
				Cold	Heated	
C₇ (<i>cont.</i>)						
	<i>i</i> -C ₃ H ₇ COCHRCH ₂ NH ₂ (Me) (R = CH ₃ , C ₂ H ₅ , <i>n</i> -C ₃ H ₇)	Am ₂ O	Am ₂ O	<i>ca.</i> 2	—	26
C₈						
	Phthalimide (Me)	Am ₂ O	C ₅ H ₅ N	1.13	—	3
	Phthalimide (Me)	C ₅ H ₅ N	—	—	0.98	44
	C ₆ H ₄ -1,2-(CO ₂ H) ₂ (Me)	Bu ₂ O	—	0.00	—	43
	C ₆ H ₄ -1,3-(CO ₂ H) ₂ (Me)	Bu ₂ O	—	0.00	—	43
	C ₆ H ₄ -1,4-(CO ₂ H) ₂ (Me)	Bu ₂ O	—	0.00	—	43
	Indole (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.81	—	7
	Indole (Me)	Am ₂ O	Xylene	1.02	1.04	24
	2-Methylbenzoselenazole (Et*)	Et ₂ O	Et ₂ O	<i>ca.</i> 1	—	36
	CH ₃ COC ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	—	—	0.15	17
	CH ₃ COC ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	—	—	0.12	27
	CH ₃ COC ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.78	27
	CH ₃ COC ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.78	27
	CH ₃ COC ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.03	27
	CH ₃ COC ₆ H ₅ (Me!)	Dioxane	Dioxane	—	0.60	42
	2-CH ₃ C ₆ H ₄ CO ₂ H (Me)	Bu ₂ O	—	1.05	—	43
	3-CH ₃ C ₆ H ₄ CO ₂ H (Me)	Bu ₂ O	—	1.05	—	43
	4-CH ₃ C ₆ H ₄ CO ₂ H (Me)	Bu ₂ O	—	1.05	—	43
	4-CH ₃ OC ₆ H ₄ CO ₂ H (Me)	<i>i</i> -Am ₂ O	—	1.00	—	43
	3-HO-4-CH ₃ OC ₆ H ₃ CHO (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	1.02	27
	3-HO-4-CH ₃ OC ₆ H ₃ CHO (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.92	27
	3-HO-4-CH ₃ OC ₆ H ₃ CHO (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.89	27
	3-CH ₃ O-4-HOC ₆ H ₃ CHO (Me)	Am ₂ O	C ₅ H ₅ N	2.03	—	2
	3-CH ₃ O-4-HOC ₆ H ₃ CHO (Me)	Am ₂ O	C ₅ H ₅ N	0.93	—	14
	3-CH ₃ O-4-HOC ₆ H ₃ CHO (Me)	<i>i</i> -Am ₂ O	—	—	0.65	27

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₈ (cont.)					
3-CH ₃ O-4-HOC ₆ H ₃ CHO (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.99	27
3-CH ₃ O-4-HOC ₆ H ₃ CHO (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.99	27
CH ₃ CONHC ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	—	—	1.01	17
CH ₃ (C ₆ H ₅)CHOH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.93	—	7
1,2-(CH ₃ O) ₂ C ₆ H ₄ (Me)	<i>i</i> -Am ₂ O	—	—	0.01	27
1,2-(CH ₃ O) ₂ C ₆ H ₄ (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.00	27
4-CH ₃ C ₆ H ₄ SO ₂ CH ₃ (Me)	<i>i</i> -Am ₂ O	Xylene (?)	+	2	54
C ₂ H ₅ NHC ₆ H ₅ (Me)	EtOPh	EtOPh	1.01	—	4
C ₂ H ₅ NHC ₆ H ₅ (Me)	EtOPh	EtOPh	0.91	—	8
C ₂ H ₅ NHC ₆ H ₅ (Me)	Am ₂ O	Am ₂ O	0.99	—	8
CH ₃ COCH(C ₂ H ₅)CO ₂ C ₂ H ₅ (Et*)	Et ₂ O	Et ₂ O	1.04	—	13
(CH ₂) ₅ N(CH ₂) ₃ NH ₂ (Me*)	Et ₂ O	Et ₂ O	1.80	—	40
C₉					
C ₆ H ₃ -1,3,5-(CO ₂ H) ₃ (Me)	Bu ₂ O	—	0.00	—	43
Indene (Me)	Am ₂ O	C ₅ H ₅ N	0.00	0.92	9
C ₆ H ₅ CH=CHCO ₂ H (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	1.15	27
C ₆ H ₅ CH=CHCO ₂ H (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.98	27
C ₆ H ₅ CH=CHCO ₂ H (Me)	<i>i</i> -Am ₂ O	Xylene	—	1.08	27
1-Methylindole (Et*)	Et ₂ O	Et ₂ O	0.00	—	13
2-Methylindole (Et*)	Et ₂ O	Et ₂ O	1.07	—	13
Skatole (Me)	Am ₂ O	Xylene	1.01	1.05	24
Skatole (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.97	—	7
7-Methylindole (Me)	Am ₂ O	Xylene	1.01	1.03	24
2- <i>o</i> -Nitrophenyl-1,3-dioxolane (Me)	Am ₂ O	C ₅ H ₅ N	0.99	—	15
C ₆ H ₅ CH ₂ CH ₂ O ₂ CH (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.08	27
C ₆ H ₅ CH ₂ CH ₂ O ₂ CH (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.51	27

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₉ (cont.)					
C ₆ H ₅ CH ₂ CH ₂ O ₂ CH (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.04	27
2-HOC ₆ H ₄ CO ₂ C ₂ H ₅ (Me)	Am ₂ O	Am ₂ O	0.99	—	1
3,4-(CH ₃ O) ₂ C ₆ H ₃ CHO (Me)	<i>i</i> -Am ₂ O	—	—	0.05	27
3,4-(CH ₃ O) ₂ C ₆ H ₃ CHO (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.36	27
3,4-(CH ₃ O) ₂ C ₆ H ₃ CHO (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.44	27
3,4-(CH ₃ O) ₂ C ₆ H ₃ CHO (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.03	27
3-CH ₃ O-4-HOC ₆ H ₄ COCH ₃ (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	1.25	27
3-CH ₃ O-4-HOC ₆ H ₄ COCH ₃ (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.91	27
3-CH ₃ O-4-HOC ₆ H ₄ COCH ₃ (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.97	27
C ₂ H ₅ (C ₆ H ₅)CHOH (Me*)	Et ₂ O	Et ₂ O	1.11	—	40
1,2,3-(CH ₃ O) ₃ C ₆ H ₃ (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.03	27
1,2,3-(CH ₃ O) ₃ C ₆ H ₃ (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.03	27
1,2,3-(CH ₃ O) ₃ C ₆ H ₃ (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.03	27
5- <i>n</i> -Hexylisoxazole (Et*)	Et ₂ O	Et ₂ O	<i>ca.</i> 1	—	11
CH ₃ COC(CH ₃)(C ₂ H ₅)- <i>n</i> -C ₃ H ₇ (Me*)	Et ₂ O	Et ₂ O	0.99	—	53
C₁₀					
C ₆ H ₂ -1,2,4,5-(CO ₂ H) ₄ (Me)	Bu ₂ O	—	0.00	—	43
1-C ₁₀ H ₇ OH (Me)	Am ₂ O	C ₅ H ₅ N	1.02	—	10
1-C ₁₀ H ₇ OH (Me)	EtOPh	MeOPh	0.93	—	8
1-C ₁₀ H ₇ OH (Me)	Am ₂ O	Am ₂ O	0.98	—	1
1-C ₁₀ H ₇ OH (Me)	<i>i</i> -Am ₂ O	—	1.01	—	43
1-C ₁₀ H ₇ OH (Et*)	Et ₂ O	Et ₂ O	1.11	—	13
2-C ₁₀ H ₇ OH (Me)	Bu ₂ O	—	1.01	—	43
2-C ₁₀ H ₇ OH (Me)	Am ₂ O	C ₅ H ₅ N	1.01	—	2
2-C ₁₀ H ₇ OH (Me)	Am ₂ O	Am ₂ O	0.99	—	1
2-C ₁₀ H ₇ OH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.93	—	7

TABLE XVIII-I (Continued)

	Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
				Cold	Heated	
C₁₀ (cont.)						
1-C ₁₀ H ₇ NH ₂ (Et*)		Et ₂ O	Et ₂ O	1.01	—	11
2-C ₁₀ H ₇ NH ₂ (Me)		Am ₂ O	Am ₂ O	1.00	1.97	4
2-C ₁₀ H ₇ NH ₂ (Me†)		Et ₂ O	Et ₂ O	—	0.99	40
2-C ₁₀ H ₇ NH ₂ (Me†)		—	—	—	1.98	40
2-C ₁₀ H ₇ NH ₂ (Et*)		Et ₂ O	Et ₂ O	1.01	—	11
1,2-(H ₂ N) ₂ C ₁₀ H ₆ (Me)		Am ₂ O	C ₅ H ₅ N	2.05	2.91	9
CH ₃ COCH ₂ COC ₆ H ₅ (Me)		Am ₂ O	Am ₂ O	0.88	1.00	3
CH ₃ COCH ₂ COC ₆ H ₅ (Me)		Am ₂ O	Am ₂ O	0.66	—	5
1,2-(CH ₃ CO ₂) ₂ C ₆ H ₄ (Me)		<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.24	27
1,2-(CH ₃ CO ₂) ₂ C ₆ H ₄ (Me)		<i>i</i> -Am ₂ O	Dioxane	—	0.73	27
1,2-(CH ₃ CO ₂) ₂ C ₆ H ₄ (Me)		<i>i</i> -Am ₂ O	Xylene	—	0.06	27
2-CH ₃ O-4-H ₂ C=CHCH ₂ C ₆ H ₃ OH (Me)		Am ₂ O	C ₅ H ₅ N	1.08	—	14
Tetralin hydroperoxide (Me)		Am ₂ O	C ₅ H ₅ N	0.98	—	33
2-CH ₃ -6- <i>i</i> -C ₃ H ₇ C ₆ H ₃ OH (Me)		Am ₂ O	C ₅ H ₅ N	1.03	—	14
2- <i>i</i> -C ₃ H ₇ -5-CH ₃ C ₆ H ₃ OH (Me)		Am ₂ O	C ₅ H ₅ N	1.00	—	14
2- <i>i</i> -C ₃ H ₇ -5-CH ₃ C ₆ H ₃ OH (Me†)		Et ₂ O	C ₆ H ₆	1.03	—	40
4-(C ₂ H ₅) ₂ NC ₆ H ₄ NO (Et*)		Et ₂ O	Et ₂ O	—	0.74	16
<i>n</i> -C ₅ H ₁₁ C≡CCH ₂ CH=CH ₂ (Et*)		C ₆ H ₆	C ₆ H ₆	—	ca. 1	45,46
<i>n</i> -C ₄ H ₉ C≡CC(CH ₃)=CHCH ₂ OH (Me)		?	?	1.05	—	49
Ascaridole (Me)		Am ₂ O	—	—	0.98	33
Ascaridole (Me)		Am ₂ O	C ₅ H ₅ N	0.38–0.60 ^d	—	33
Camphor oxime (Me)		Am ₂ O	C ₅ H ₅ N	1.01	—	2
Camphor oxime (Et)		<i>i</i> -Am ₂ O	C ₅ H ₅ N	1.17	—	7
Borneol (Me)		Am ₂ O	C ₅ H ₅ N	0.99	—	2
Borneol (Me)		Am ₂ O	C ₅ H ₅ N	0.99	—	14
Geraniol (Me)		Am ₂ O	C ₅ H ₅ N	1.04	—	14

^d Apparent active H: 0.38 at 15°; 0.60 at 25°.

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C ₁₀ (cont.)					
Geraniol (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	1.01	—	7
Terpineol (Me)	Am ₂ O	C ₅ H ₅ N	1.01	—	14
Linalool (Me)	Am ₂ O	C ₅ H ₅ N	1.01	—	14
Menthene-3 hydroperoxide (Me)	Am ₂ O	C ₅ H ₅ N	0.91	—	33
Menthol (Me)	Am ₂ O	C ₅ H ₅ N	1.01	—	2,14
Menthol (Me)	Am ₂ O	MeOPh	0.98	—	6
Menthol (Me)	Am ₂ O	Xylene	0.99	—	6
Menthol (Me)	Am ₂ O	Mesitylene	1.01	—	6
Menthol (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.99	—	7
Citronellol (Me)	Am ₂ O	C ₅ H ₅ N	1.06	—	14
<i>i</i> -C ₃ H ₇ COC(CH ₃) ₂ CH(OH)C ₂ H ₅ (Me)	Am ₂ O	C ₅ H ₅ N	1.01	—	34
C ₁₁					
C ₆ H(CO ₂ H) ₅ (Me)	Bu ₂ O	—	0.00	—	43
C ₆ H ₅ C≡CCH ₂ CH=CH ₂ (Et*)	C ₆ H ₆	C ₆ H ₆	—	<i>ca.</i> 1	45,46
3-Ethyl-5-phenylpyrazole (Et*)	Et ₂ O	Et ₂ O	1.06	—	11
3,4-(CH ₃ O) ₂ C ₆ H ₃ CH=CHCH ₃ (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.04	27
3,4-(CH ₃ O) ₂ C ₆ H ₃ CH=CHCH ₃ (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.06	27
CH ₃ COC ₆ H ₄ -2,4,6-(CH ₃) ₃ (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.99	17
<i>n</i> -C ₄ H ₉ C≡C—C(CH ₃)=CHCH(CH ₃)OH (Me)	?	?	1.00	—	49
Menthone semicarbazone (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	1.96	2.00	3
<i>n</i> -C ₆ H ₁₃ CH(CH ₃)CH ₂ CH(CH ₃)OH (Me)	?	?	1.05	—	49
Methyl 2,3,4,6-tetramethyl- α -D-glucoside (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.33	27
Methyl 2,3,4,6-tetramethyl- α -D-glucoside (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.35	27
Methyl 2,3,4,6-tetramethyl- α -D-glucoside (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.24	27
Methyl 2,3,4,6-tetramethyl- β -D-glucoside (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.18	27
Methyl 2,3,4,6-tetramethyl- β -D-glucoside (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.09	27

TABLE XVIII-I (Continued)

	Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
				Cold	Heated	
C ₁₂						
	2,4,6-(O ₂ N) ₃ C ₆ H ₂ N ₂ C ₆ H ₄ -4-NH ₂ (Me)	Bu ₂ O	Xylene	2.03	3.32	20
	2,4,6-(O ₂ N) ₃ C ₆ H ₂ N ₂ C ₆ H ₄ -4-NH ₂ (Me)	<i>i</i> -Am ₂ O	Xylene	2.09	3.62	20
	Carbazole (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.99	—	7
	Carbazole (Et*)	Et ₂ O	Et ₂ O	1.03	—	11
	(C ₆ H ₅ N=) ₂ (Me)	Bu ₂ O	Bu ₂ O	0.24	0.29	20
	(C ₆ H ₅) ₂ NH (Me)	EtOPh	EtOPh	0.84	—	8
	(C ₆ H ₅) ₂ NH (Me)	<i>i</i> -Am ₂ O	—	—	1.07	17
	(C ₆ H ₅) ₂ NH (Me)	EtOPh	EtOPh	0.98	—	4
	(C ₆ H ₅) ₂ NH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	1.01	—	7
	(C ₆ H ₅) ₂ NH (Et*)	Et ₂ O	Et ₂ O	0.94	—	11
	4-H ₂ NC ₆ H ₄ N ₂ C ₆ H ₅ (Me)	Bu ₂ O	Bu ₂ O	1.69	2.18	20
	4-H ₂ NC ₆ H ₄ N=NC ₆ H ₅ (Me)	Am ₂ O	C ₅ H ₅ N	1.07	2.08	6
	4-H ₂ NC ₆ H ₄ N=NC ₆ H ₅ (Me)	Am ₂ O	Xylene	0.99	2.05	6
	(4-H ₂ NC ₆ H ₄ —) ₂ (Me)	Am ₂ O	C ₅ H ₅ N	1.92	3.11	9
	(4-H ₂ NC ₆ H ₄ —) ₂ (Me†)	Et ₂ O	Et ₂ O	2.00	—	40
	(4-H ₂ NC ₆ H ₄ —) ₂ (Me)	Am ₂ O	MeOPh	1.99	3.14	9
	(4-H ₂ NC ₆ H ₄ —) ₂ (Me†)	—	—	—	2.00	40
	(4-H ₂ NC ₆ H ₄ —) ₂ (Et*)	Et ₂ O	Et ₂ O	2.04	—	11
	(C ₆ H ₅ NH—) ₂ (Et*)	Et ₂ O	Et ₂ O	2.04	—	11
	(C ₆ H ₅) ₂ NNH ₂ (Et*)	Et ₂ O	Et ₂ O	1.05	—	11
	2,4,5,6-(CH ₃) ₄ C ₆ HCH ₂ (OH)CN (Me)	<i>i</i> -Am ₂ O	—	ca. 1	—	31
	<i>n</i> -C ₄ H ₉ C≡CC(CH ₃)=CHC(CH ₃) ₂ OH (Me)	?	?	0.95	—	49
	CH ₃ (CH ₂) ₁₀ CO ₂ H (Me)	Am ₂ O	C ₅ H ₅ N	0.99	—	12
C ₁₃						
	Euxanthone (Me)	Am ₂ O	C ₅ H ₅ N	1.99	—	3
	2-O ₂ NC ₆ H ₄ CO ₂ H·C ₆ H ₃ (NO ₂) ₃ (Me)	Am ₂ O	C ₅ H ₅ N	2.15	2.81	6

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₁₃ (cont.)					
2-O ₂ NC ₆ H ₄ CO ₂ H·C ₆ H ₃ (NO ₂) ₃ (Me)	Am ₂ O	Xylene	2.03	3.11	6
Fluorene (Me)	Am ₂ O	C ₅ H ₅ N	0.00	1.04	9
(C ₆ H ₅) ₂ CO (Me)	<i>i</i> -Am ₂ O	—	—	0.02	17
4-H ₂ NC ₆ H ₄ COC ₆ H ₅ (Et*)	Et ₂ O	Et ₂ O	<i>ca.</i> 1	—	28
C ₆ H ₅ CH=NNHC ₆ H ₅ (Et*)	Et ₂ O	Et ₂ O	1.16	—	13
(C ₆ H ₅) ₂ CHOH (Me)	Am ₂ O	C ₅ H ₅ N	0.95	—	2
(C ₆ H ₅) ₂ CHOH (Me)	Am ₂ O	MeOPh	0.94	—	6
(C ₆ H ₅) ₂ CHOH (Me)	Am ₂ O	Xylene	0.90	—	6
(C ₆ H ₅) ₂ CHOH (Me)	Am ₂ O	Mesitylene	1.14	—	6
(C ₆ H ₅) ₂ CHOH (Me)	<i>i</i> -Am ₂ O	—	—	1.02	17
(C ₆ H ₅ NH) ₂ CO (Me)	Am ₂ O	C ₅ H ₅ N	2.13	—	3
C ₆ H ₅ (C ₆ H ₅ CH ₂)NNH ₂ (Et*)	Et ₂ O	Et ₂ O	1.12	—	11
C₁₄					
Alizarin (Me)	Am ₂ O	C ₅ H ₅ N	2.03	—	2
Quinizarin (Me)	Am ₂ O	C ₅ H ₅ N	1.98	—	2
(C ₆ H ₅ CO—) ₂ (Me)	<i>i</i> -Am ₂ O	—	—	0.09	17
(2-H ₂ NC ₆ H ₄ CH=) ₂ (Me)	Am ₂ O	C ₅ H ₅ N	2.21	2.90	9
C ₆ H ₅ COCH ₂ C ₆ H ₅ (Me)	Am ₂ O	Am ₂ O	0.12	—	1
C ₆ H ₅ COCH ₂ C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	—	—	0.06	17
C ₆ H ₅ COCH ₂ C ₆ H ₅ (Me!)	Dioxane	Dioxane	—	0.24	42
C ₆ H ₅ COCH(OH)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	—	—	1.04	27
C ₆ H ₅ COCH(OH)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	—	—	1.00	42
C ₆ H ₅ COCH(OH)C ₆ H ₅ (Me)	Am ₂ O	C ₅ H ₅ N	1.07	—	2
C ₆ H ₅ COCH(OH)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	1.25	27
C ₆ H ₅ COCH(OH)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	Dioxane	—	1.35	27
C ₆ H ₅ COCH(OH)C ₆ H ₅ (Me)	Am ₂ O	Am ₂ O	—	1.03	1

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₁₄ (cont.)					
C ₆ H ₅ COCH(OH)C ₆ H ₅ (Me [†])	Dioxane	Dioxane	—	1.2–1.3	42
(—CONHC ₆ H ₅) ₂ (Me)	Am ₂ O	C ₅ H ₅ N	2.20	—	3
α-[HON=C(C ₆ H ₅)—] ₂	Am ₂ O	C ₅ H ₅ N	2.03	—	2
C ₆ H ₅ CONHC ₆ H ₄ -2-CH ₃ (Me)	Am ₂ O	C ₅ H ₅ N	1.09	—	3
C ₆ H ₅ CONHCH ₂ C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	—	—	1.01	17
C ₆ H ₅ COCH(OH)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	—	—	1.02	17
C ₆ H ₅ COCH(OH)C ₆ H ₅ (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	1.03	—	7
4-(CH ₃) ₂ NC ₆ H ₄ N ₂ C ₆ H ₅ (Me)	Bu ₂ O	Bu ₂ O	0.33	0.42	20
4-Acetyl- <i>s</i> -hydrindacene (Me)	?	?	0.30	—	38
C₁₅					
Chrysin (Me)	Am ₂ O	C ₅ H ₅ N	2.05	—	3
Fisetin (Me)	Am ₂ O	C ₅ H ₅ N	3.98	—	3
Morin (Me)	Am ₂ O	C ₅ H ₅ N	5.00	—	3
(C ₆ H ₅ CO) ₂ CHBr (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.06	17
3,4-Diphenylisoxazolone (Me)	<i>i</i> -Am ₂ O	<i>i</i> -Am ₂ O	—	<i>ca.</i> 1	19
(C ₆ H ₅ CO) ₂ CH ₂ (Me)	Am ₂ O	Am ₂ O	0.95	—	5
(C ₆ H ₅ CO) ₂ CH ₂ (Me)	<i>i</i> -Am ₂ O	Xylene	—	1.06	17
C ₆ H ₅ COCH(O ₂ CH)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.86	27
C ₆ H ₅ COCH(O ₂ CH)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.05	27
C ₆ H ₅ COCH(OCH ₃)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.07	27
C ₆ H ₅ COCH(OCH ₃)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.13	27
4-CH ₃ C ₆ H ₄ SO ₂ CH ₂ CH ₂ C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	Xylene (?)	—	≥ 1	54
C ₂ H ₅ (C ₆ H ₅) ₂ CHOH (Me*)	Et ₂ O	Et ₂ O	1.25	—	40
9-Acetyl-5,6,7,8-tetrahydrobenz[<i>f</i>]indan (Me)	?	?	0.62	—	38
2,4,6-(CH ₃) ₃ C ₆ H ₂ CH ₂ CO- <i>t</i> -C ₄ H ₉ (Me)	Am ₂ O	C ₅ H ₅ N	<i>ca.</i> 0	—	32
[CH ₃ (CH ₂) ₄ C≡C] ₂ CH ₂ (Et)	Et ₂ O	Et ₂ O	0.00	0.57	23
[CH ₃ (CH ₂) ₄ C≡C] ₂ CH ₂ (Et)	Et ₂ O-C ₆ H ₆	Et ₂ O-C ₆ H ₆	—	1.32	23

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₁₆					
"Di-indole" (Me)	Am ₂ O	Xylene	2.04	2.04	24
Hematein (Me)	Am ₂ O	C ₅ H ₅ N	4.07	—	3
1-C ₆ H ₅ NHC ₁₀ H ₇ (Me)	EtOPh	EtOPh	1.00	—	4
2-C ₆ H ₅ NHC ₁₀ H ₇ (Me)	EtOPh	EtOPh	1.06	—	4
(C ₆ H ₅ CO) ₂ CHCH ₃ (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.16	17
C ₆ H ₅ COCH(O ₂ CCH ₃)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.58	27
C ₆ H ₅ COCH(O ₂ CCH ₃)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.42	27
C ₆ H ₅ COCH(O ₂ CCH ₃)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	Xylene	—	0.10	27
C ₆ H ₅ COCH(NHCOCH ₃)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	—	<i>ca.</i> 1	—	31
Brazilin (C ₁₆ H ₁₄ O ₅ ·1.5H ₂ O) (Me)	Am ₂ O	C ₅ H ₅ N	3.97	—	3
9-Acetyl-1,2,3,4,5,6,7,8-octahydroanthracene (Me)	?	?	0.95	—	38
Hematoxylin (C ₁₆ H ₁₄ O ₆ ·3H ₂ O) (Me)	Am ₂ O	C ₅ H ₅ N	5.01	—	3
Glucose pentaacetate (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	1.6	27
Glucose pentaacetate (Me)	<i>i</i> -Am ₂ O	Dioxane	—	1.9	27
2,4,6-(CH ₃) ₃ C ₆ H ₂ C(OH)(CH ₃)CO- <i>t</i> -C ₄ H ₉ (Me)	Am ₂ O	C ₅ H ₅ N	<i>ca.</i> 1	—	32
2,4,6-(CH ₃) ₃ C ₆ H ₂ COC(OH)(CH ₃)- <i>t</i> -C ₄ H ₉ (Me)	Am ₂ O	C ₅ H ₅ N	<i>ca.</i> 1	—	32
CH ₃ (CH ₂) ₁₄ CO ₂ H (Me)	Am ₂ O	C ₅ H ₅ N	0.97	—	12
<i>n</i> -C ₁₆ H ₃₃ OH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	0.79	—	7
C₁₇					
(C ₆ H ₅ C≡C) ₂ CH ₂ (Et*)	Et ₂ O	Et ₂ O	—	0.95	46,45
(C ₆ H ₅ C≡C) ₂ CH ₂ (Et*)	C ₆ H ₅	C ₆ H ₅	—	1.84	46,45
C ₆ H ₅ C(=NH)-1-C ₁₀ H ₇ (Et*)	Et ₂ O	Et ₂ O	1.08	—	11
(CH ₃) ₂ C(COC ₆ H ₅) ₂ (Me)	Am ₂ O	Am ₂ O	0.00	—	5
Morphine (C ₁₇ H ₁₉ NO ₃) (Me)	Am ₂ O	C ₅ H ₅ N	1.95	1.96	6
Morphine (C ₁₇ H ₁₉ NO ₃ ·H ₂ O) (Me)	Am ₂ O	C ₅ H ₅ N	3.96	3.96	6
Cocaine (C ₁₇ H ₂₁ NO ₄ ·HCl) (Me)	Am ₂ O	C ₅ H ₅ N	1.21	1.19	6

TABLE XVIII-I (Continued)

	Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
				Cold	Heated	
C₁₇ (cont.)						
	4-(CH ₃) ₂ NC ₆ H ₄ C(=NH)C ₆ H ₄ -4-N(CH ₃) ₂ (Et*)	Et ₂ O	Et ₂ O	1.04	—	11
	Atropine (Me)	Am ₂ O	C ₅ H ₅ N	1.12	1.20	6
C₁₈						
	4-H ₂ NC ₆ H ₄ N=NC ₆ H ₅ ·C ₆ H ₃ (NO ₂) ₃ (Me)	Am ₂ O	Xylene	1.03	2.02	6
	4-C ₆ H ₅ NHC ₆ H ₄ N ₂ C ₆ H ₅ (Me)	Bu ₂ O	Bu ₂ O	1.26	1.42	20
	"Di-skatole" (Me)	Am ₂ O	Xylene	2.05	2.00	24
	"Di-7-methylindole" (Me)	Am ₂ O	Xylene	1.95	1.90	24
	2,2'-Bis-(o-nitrophenyl)-4,4'-bi-1,3-dioxolanyl (Me)	Am ₂ O	C ₅ H ₅ N	1.28	—	15
	3,4-(CH ₃ O) ₂ C ₆ H ₃ COCH=CHC ₆ H ₃ -2-OH-4-OCH ₃ (Me)	Am ₂ O	C ₅ H ₅ N	1.05	—	3
	2,4,5,6-(CH ₃) ₄ C ₆ HCOCH(NH ₂ ·HCl)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	—	<i>ca.</i> 3	<i>ca.</i> 4	31
	<i>n</i> -C ₈ H ₁₇ CH=CH(CH ₂) ₇ CO ₂ H (Me)	Am ₂ O	C ₅ H ₅ N	0.97	—	12
	<i>n</i> -C ₆ H ₁₃ CH(OH)CH ₂ CH=CH(CH ₂) ₇ CO ₂ H (Me)	Am ₂ O	C ₅ H ₅ N	1.98	—	12
	CH ₃ (CH ₂) ₁₆ CO ₂ H (Me)	Am ₂ O	C ₅ H ₅ N	1.06	—	12
	"Dihydroxystearic acid" (Me)	Am ₂ O	C ₅ H ₅ N	2.95	—	12
	[(<i>t</i> -C ₄ H ₉) ₂ C(OH)—] ₂ (Me)	Am ₂ O	C ₅ H ₅ N	1.90	—	29
C₁₉						
	9-Phenylfluorene (Me)	Am ₂ O	C ₅ H ₅ N	0.00	1.10	9
	9-Phenyl-9-fluorenol (Me)	Am ₂ O	C ₅ H ₅ N	0.36-0.41	1.02-1.17	9
	9-Phenyl-9-fluorenol (Me)	Am ₂ O	MeOPh	—	1.02	9
	Aurin (Me)	C ₅ H ₅ N	—	—	1.97	44
	2-O ₂ NC ₆ H ₄ (C ₆ H ₅) ₂ CH (Me)	Am ₂ O	C ₅ H ₅ N	1.01	—	15
	(C ₆ H ₅) ₃ COH (Me)	Am ₂ O	C ₅ H ₅ N	1.00	—	2
	(C ₆ H ₅) ₃ COH (Et)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	1.05	—	7
	3,9-Bis-(o-nitrophenyl)-2,4,8,10-tetroxaspiro[5.5]-hendecane (Me)	Am ₂ O	C ₅ H ₅ N	1.27	—	15

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₁₉ (<i>cont.</i>)					
Cinchonine (Me)	Am ₂ O	C ₅ H ₅ N	1.22	1.25	6
Cinchonidine (Me)	Am ₂ O	C ₅ H ₅ N	1.11	1.08	6
C₂₀					
Fluoresceïn (Me)	Am ₂ O	C ₅ H ₅ N	—	2.11	2
<i>p</i> -Hydroxydiphenylphthalide (Me)	Am ₂ O	Am ₂ O	—	1.04	51
K salt of phenolphthaleïn (Et)	Et ₂ O	Et ₂ O	<i>ca.</i> 1	—	48
Phenolphthaleïn (Et)	Et ₂ O	Et ₂ O	0.00	—	48
Phenolphthaleïn (Me)	Am ₂ O	Am ₂ O	—	0.15	51
Phenolphthaleïn (Me)	Am ₂ O	C ₅ H ₅ N	—	1.95	51
Phenolphthaleïn (Me)	C ₅ H ₅ N	—	—	2.07	44
Benzenehydroquinonephthaleïn (Me)	Am ₂ O	C ₅ H ₅ N	—	2.14	51
Phenolresorcinolphthaleïn (Me)	Am ₂ O	Am ₂ O	—	0.35	51
Phenolresorcinolphthaleïn (Me)	Am ₂ O	C ₅ H ₅ N	—	3.24	51
(2-C ₁₀ H ₇) ₂ NH (Me)	EtOPh	EtOPh	1.08	—	4
C ₆ H ₅ COCH(C ₆ H ₅) ₂ (Me)	<i>i</i> -Am ₂ O	—	—	0.14	17
C ₆ H ₅ COCH(C ₆ H ₅) ₂ (Me)	<i>i</i> -Am ₂ O	—	—	0.02	27
C ₆ H ₅ COCH(C ₆ H ₅) ₂ (Me)	<i>i</i> -Am ₂ O	C ₅ H ₅ N	—	0.11	27
C ₆ H ₅ COCH(C ₆ H ₅) ₂ (Me)	<i>i</i> -Am ₂ O	Dioxane	—	0.48	27
C ₆ H ₅ COCH(C ₆ H ₅) ₂ (Me)	Dioxane	Dioxane	—	0.11	42
Benzenepyrocatecholphthaleïn (Me)	Am ₂ O	Am ₂ O	—	0.22	51
Benzenepyrocatecholphthaleïn (Me)	Am ₂ O	C ₅ H ₅ N	—	2.26	51
2,4,5,6-(CH ₃) ₄ C ₆ HCOCH(NHCOCH ₃)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	—	<i>ca.</i> 2	—	31
Quinidine (Me)	Am ₂ O	C ₅ H ₅ N	0.86	0.86	6
Quinine (Me)	Am ₂ O	C ₅ H ₅ N	0.97	1.18	6
Quinine hydrate (C ₂₀ H ₂₄ N ₂ O ₂ ·3H ₂ O) (Me)	Am ₂ O	C ₅ H ₅ N	7.08	—	6
(4-CH ₃ OC ₆ H ₄) ₂ CHC(C ₂ H ₅) ₂ OH (Me)	?	?	0.80-0.85	—	50

TABLE XVIII-I (Continued)

	Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
				Cold	Heated	
C₂₁						
	13-Dibenzo[<i>a,i</i>]fluorene (Me)	-Am ₂ O	C ₅ H ₅ N	0.00	1.14	9
	4-CH ₃ C ₆ H ₄ SO ₂ CH ₂ CH(C ₆ H ₅) ₂ (Me)	<i>i</i> -Am ₂ O	Xylene (?)	—	≥ 1	54
	Phenolphthalein monomethyl ether (Me)	Am ₂ O	Am ₂ O	—	1.08	51
	Strychnine (Me)	Am ₂ O	C ₅ H ₅ N	0.70	—	25
	Strychnine (Me)	Am ₂ O	MeOPh	1.31	1.63	25
	Dihydrostrychnine (Me)	Am ₂ O	MeOPh	1.15	1.24	25
	Tetrahydrostrychnine (Me)	Am ₂ O	MeOPh	1.58	1.77	25
C₂₂						
	3,6-Dimethyl-4,5-diphenylphthalic anhydride (Me)	?	?	0.80	—	30
	3,3',3''-Trimethoxy-4,4'-dihydroxy fuchsonone (Me)	C ₅ H ₅ N	—	—	2.06	44
	Narcotine (Me)	Am ₂ O	C ₅ H ₅ N	0.00	—	6
	Desoxyvomisine (Me)	Am ₂ O	MeOPh	1.35	1.66	25
	Vomicine (Me)	Am ₂ O	C ₅ H ₅ N	1.04	—	25
	Vomicine (Me)	Am ₂ O	MeOPh	2.06	2.13	25
	Vomicine (Me)	Am ₂ O	Xylene	1.71	2.09	25
	Vomicidine (Me)	Am ₂ O	MeOPh	1.03	0.98	25
	Dihydrovomisine (Me)	Am ₂ O	MeOPh	1.43	1.72	25
C₂₃						
	Brucine (Me)	Am ₂ O	C ₅ H ₅ N	0.09	—	6
	Brucine (Me)	Am ₂ O	C ₅ H ₅ N	0.81	—	25
	Brucine (Me)	Am ₂ O	MeOPh	0.88	0.93	25
	Dihydrobrucine (Me)	Am ₂ O	MeOPh	0.81	0.99	25
	2,4,5,6-(CH ₃) ₄ C ₆ HC(O ₂ CCH ₃) ₂ CH(NHCOCH ₃)C ₆ H ₅ (Me)	<i>i</i> -Am ₂ O	—	<i>ca.</i> 0	—	31

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₂₄					
"Tri-indole" (Me)	Am ₂ O	Xylene	3.04	3.10	24
Phenolthymolphthaleïn (Me)	Am ₂ O	Am ₂ O	—	0.23	51
Phenolthymolphthaleïn (Me)	Am ₂ O	C ₅ H ₅ N	—	2.17	51
Thymolpyrocatecholpthaleïn (Me)	Am ₂ O	C ₅ H ₅ N	—	3.37	51
Thymolresorcinolphthaleïn (Me)	Am ₂ O	Am ₂ O	—	0.15	51
Thymolresorcinolphthaleïn (Me)	Am ₂ O	C ₅ H ₅ N	—	3.32	51
C₂₅					
Phenol(methyl-4-thymol)phthaleïn	Am ₂ O	Am ₂ O	—	1.02	51
(Methyl-4-thymol)pyrocatecolphthaleïn	Am ₂ O	C ₅ H ₅ N	—	2.21	51
(Methyl-4-thymol)resorcinolphthaleïn (Me)	Am ₂ O	Am ₂ O	—	2.03	51
(Methyl-4-thymol)resorcinolphthaleïn (Me)	Am ₂ O	C ₅ H ₅ N	—	2.19	51
C₂₆					
1-Methyl-2,5,6-triphenyl-7-oxo-1,4-methano-1,2,3,4-tetrahydrobenzene (Me)	?	?	ca. 0	—	30
CH ₃ (CH ₂) ₂₄ CO ₂ H (Me)	Am ₂ O	C ₅ H ₅ N	1.00	—	12
C₂₇					
1,4-Dimethyl-3-benzoyl-5,6-diphenyl-7-oxo-1,4-methano-1,2,3,4-tetrahydrobenzene (Me)	?	?	0.80	—	30
1-Methyl-3,5,6-triphenyl-7-hydroxy-7-R-1,4-methano-1,2,3,4-tetrahydrobenzene (Me) (R = CH ₃ , C ₆ H ₅ , 1-C ₁₀ H ₇)	?	?	ca. 1	—	30
C₃₁					
13- α -Naphthyl-13-dibenzo[<i>a,i</i>]fluorene (Me)	Am ₂ O	C ₅ H ₅ N	0.00	1.02	9
13- α -Naphthyl-13-dibenzo[<i>a,i</i>]fluorenol (Me)	Am ₂ O	C ₅ H ₅ N	0.16	0.90	9

TABLE XVIII-I (Continued)

Sample (G.R.)	G. R. Solvent	Sample Solvent	Apparent "Active" H		Ref.
			Cold	Heated	
C₃₁ (<i>cont.</i>)					
1,2,5,6-Tetraphenyl-7-oxo-1,4-methano-1,2,3,4-tetrahydrobenzene (Me)	?	?	<i>ca.</i> 0	—	39
MesCOCH(Mes)CH ₂ COMes ^e (Me)	<i>i</i> -Am ₂ O	<i>i</i> -Am ₂ O	<i>ca.</i> 1	<i>ca.</i> 1.5	52
C₃₂					
Etioporphyrin II (Me)	Bu ₂ O	C ₆ H ₆	2.06	—	37
C₃₃					
<i>N</i> -Methyletioporphyrin II (Me)	Bu ₂ O	C ₆ H ₆	1.04	—	37
C₃₄					
3,3a,5,6-Tetraphenyl-3a,4,7,7a-tetrahydro-1-indenone (Me)	?	?	<i>ca.</i> 1	—	30

^e Mes = mesityl = 2,4,6-(CH₃)₃C₆H₂—.

REFERENCES FOR TABLE XVIII-I

- (1) Hibbert and Sudborough, *Proc. Chem. Soc.*, 19, 285-6 (1903); *J. Chem. Soc.*, 85, 933-8 (1904).
- (2) Zerewitinoff, *Ber.*, 40, 2023-31 (1907).
- (3) Zerewitinoff, *Ber.*, 41, 2233-43 (1908).
- (4) Sudborough and Hibbert, *J. Chem. Soc.*, 95, 477-80 (1909).
- (5) Smedley, *J. Chem. Soc.*, 97, 1484-94 (1910).
- (6) Zerewitinoff, *Ber.*, 43, 3590-5 (1910).
- (7) Oddo, *Ber.*, 44, 2048-52 (1911).
- (8) Hibbert, *J. Chem. Soc.*, 101, 328-41 (1912).
- (9) Zerewitinoff, *Ber.*, 45, 2384-9 (1912).
- (10) Zerewitinoff, *Ber.*, 47, 2417-23 (1914).
- (11) Moureu and Mignonac, *Compt. rend.*, 158, 1624-31 (1914).
- (12) Zerewitinoff, *Z. anal. Chem.*, 52, 729-37 (1914).
- (13) Ciusa, *Gazz. chim. ital.*, 50, 11, 53-5 (1920); *Chem. Abstr.*, 15, 837 (1921).
- (14) Zerewitinoff, *Z. anal. Chem.*, 68, 321-7 (1926).
- (15) Tanasescu, *Bull. soc. chim.*, [4], 39, 1443-55 (1926).
- (16) Gilman and Fothergill, *J. Am. Chem. Soc.*, 49, 2815-8 (1927).
- (17) Kohler, Stone, and Fuson, *J. Am. Chem. Soc.*, 49, 3181-8 (1927).
- (18) Job and Dusollier, *Compt. rend.*, 184, 1454-6 (1927); *Chem. Zentr.*, 1927, 11, 920; *Chem. Abstr.*, 21, 3049 (1927).
- (19) Kohler and Blatt, *J. Am. Chem. Soc.*, 50, 504-15 (1928).
- (20) Gilman and Fothergill, *J. Am. Chem. Soc.*, 50, 867-9 (1928).
- (21) Gilman and Fothergill, *Bull. soc. chim.*, [4], 45, 1132-6 (1929).
- (22) Gilman, Fothergill, and Towne, *J. Am. Chem. Soc.*, 52, 405-7 (1930).
- (23) Tchao Yin Lai, *Bull. soc. chim.*, [4], 53, 1537-43 (1933).
- (24) Schmitz-Dumont and Hamann, *Ber.*, 66B, 71-6 (1933).
- (25) Wieland and Holscher, *Ann.*, 500, 70-91 (1933).
- (26) Wiley and Adkins, *J. Am. Chem. Soc.*, 60, 914-8 (1938).
- (27) Lieff, Wright, and Hibbert, *J. Am. Chem. Soc.*, 61, 865-7 (1939).
- (28) Nesmeyanov and Sazonova, *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1941, 499-519; *Chem. Abstr.*, 37, 2724 (1943).
- (29) Stevens and Mowat, *J. Am. Chem. Soc.*, 64, 554-6 (1942).
- (30) Allen and Van Allan, *J. Am. Chem. Soc.*, 64, 1260-7 (1942).
- (31) Weissberger and Glass, *J. Am. Chem. Soc.*, 64, 1724-7 (1942).
- (32) Fuson and Robertson, *J. Org. Chem.*, 7, 466-71 (1942).
- (33) Freibs, *Ber.*, 75B, 953-7 (1942).
- (34) Erickson and Kitchens, *J. Am. Chem. Soc.*, 68, 492-6 (1946).
- (35) Spaeth, Geissman, and Jacobs, *J. Org. Chem.*, 11, 399-404 (1946).
- (36) Courtot and Devalotte, *Compt. rend.*, 223, 64-7 (1946); *Chem. Abstr.*, 41, 446 (1947).
- (37) Ellingson and Corwin, *J. Am. Chem. Soc.*, 68, 1112-5 (1946).
- (38) Arnold and Rondestvedt, *J. Am. Chem. Soc.*, 68, 2176-8 (1946).
- (39) Allen and Van Allan, *J. Am. Chem. Soc.*, 68, 2387-90 (1946).
- (40) Terent'ev, Shcherbakova, and Kremenskaya, *J. Gen. Chem. (U.S.S.R.)*, 17, 100-4 (1947); *Chem. Abstr.*, 42, 109 (1948).
- (41) Hollyday and Cottle, *Ind. Eng. Chem., Anal. Ed.*, 14, 774-6 (1942).
- (42) Wright, *J. Am. Chem. Soc.*, 61, 1152-6 (1939).
- (43) Fuchs, Ishler, and Sandhoff, *Ind. Eng. Chem., Anal. Ed.*, 12, 507-9 (1940).
- (44) Lehman and Basch, *Ind. Eng. Chem., Anal. Ed.*, 17, 428-9 (1945).
- (45) Grignard and Lepayre, *Compt. rend.*, 192, 250-3 (1931); *Chem. Abstr.*, 25, 2421 (1931).
- (46) Grignard and Lepayre, *Bull. soc. chim.*, [4], 43, 930-1 (1928).

- (47) Rebek and Mandrino, *Österr. Chem.-Ztg.*, 41, 49-52 (1938); *Chem. Zentr.*, 1938,11, 1204; *Chem. Abstr.*, 32, 3755 (1938).
- (48) Oddo and Vassallo, *Gazz. chim. ital.*, 42,11, 204-36 (1912); *Chem. Abstr.*, 7, 341 (1913).
- (49) Cymerman, Heilbron, and Jones, *J. Chem. Soc.*, 1944, 144-7.
- (50) Földi and Demjén, *Ber.*, 74B, 930-4 (1941).
- (51) Lin Che Kin, *Ann. chim.*, [11], 13, 317-99 (1940).
- (52) Lutz and Kibler, *J. Am. Chem. Soc.*, 62, 360-72 (1940).
- (53) Lester and Proffitt, *J. Am. Chem. Soc.*, 71, 1877-8 (1949).
- (54) Kohler and Potter, *J. Am. Chem. Soc.*, 57, 1316-21 (1935).

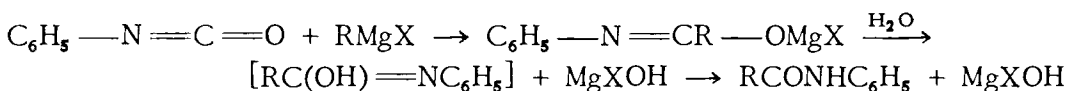
CHAPTER XIX

Reactions of Grignard Reagents with Miscellaneous Nitrogen Compounds*

ISOCYANATES AND ISOTHIOCYANATES

It was reported by Blaise¹ that phenyl isocyanate ($\text{C}_6\text{H}_5\text{—N}=\text{C}=\text{O}$) reacts with organomagnesium iodides (RMgl) to form products which, upon hydrolysis, yield anilides ($\text{RCONHC}_6\text{H}_5$).

Nothing is certainly known concerning the mechanism, or even the order, of the reaction. However, the studies of Gilman *et al.*^{2,3} make it appear probable that the condensation of phenyl isocyanate with one molecule of Grignard reagent is essentially an ionic addition at the terminal ($\text{C}=\text{O}$) double bond.



Thus far the reaction proceeds smoothly at or below the boiling point of ethyl ether, usually with very good (80–90 percent) yields. Even in the presence of a large excess of Grignard reagent further reaction does not take place at an appreciable rate in ether solution (Gilman *et al.*, *loc. cit.*^{2,3}).

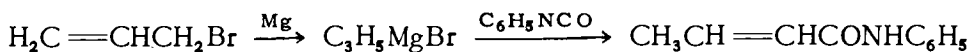
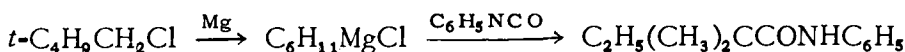
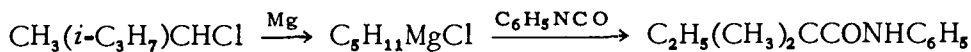
*The present authors have found the preparation of this (frankly compilative) chapter one of the least enjoyable tasks of the project undertaken. In so far as the essentially ionic addition reactions discussed are concerned, the facts may generally be taken to be substantially as reported. In oxidation-reduction reactions (especially those involving "non-reducing" Grignard reagents), however, it is felt that the present "factual" foundation affords far too slippery a footing for confident theorization or profitable speculation. In some individual cases, specific reasons for this general dysphoria are stated in the following text, and lines of investigation are suggested. Without intended criticism of earlier investigators who (having no reason to suspect the profound influence on some reactions of traces of metallic impurities in reagent magnesium) honestly reported their observations of the results of technically admirable work, it is suggested that the interested reader may here find many subjects worthy of re-examination.

¹ Blaise, *Compt. rend.*, 132, 38–41 (1901); *Chem. Zentr.*, 1901, I, 298.

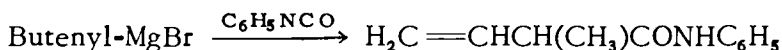
² Gilman and Kinney, *J. Am. Chem. Soc.*, 46, 493–7 (1924).

³ Gilman, Kirby, and Kinney, *J. Am. Chem. Soc.*, 51, 2252–61 (1929).

Because of the tractability of the reaction, and the ready isolability of the well-characterized products, the condensation of an aryl isocyanate with a Grignard reagent has been recommended as a means for the identification of alkyl halides or of alcohols readily convertible to halides.^{4,5} However, it should be noted in this connection that the reaction sometimes involves rearrangement. Thus, Schwartz and Johnson⁶ found that 2-chloro-2-methylbutane, neopentyl chloride, and allyl bromide all give rearranged products.

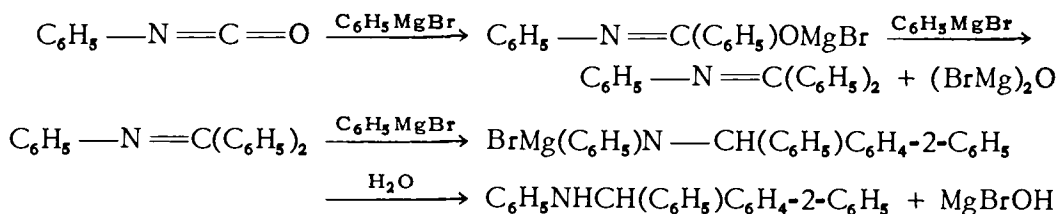


Young and Roberts⁷ also report that the only product isolated by them (in 74 percent yield) from the reaction of butenylmagnesium bromide with phenyl isocyanate was the anilide of the terminally double-bonded acid.



So far as one may judge from the available data the reactions of Grignard reagents with aryl isothiocyanates appear to be similar in all respects to those with aryl isocyanates. According to Sachs and Loevy,⁸ methyl isothiocyanate and allyl isothiocyanate also react similarly. Reactions which are reported as proceeding "normally" are recorded in Table XIX-I.

Gilman *et al.* (*loc. cit.*³) found that, under "forced reaction" conditions (*i.e.*, six to eight hours reflux in ether-toluene at 70–80°), phenyl isocyanate reacts with three molecules of phenylmagnesium bromide to yield (44 percent) a product which they identified as phenyl-*o*-biphenylmethyl-aniline. Under the same conditions the same product was obtained in about the same yields from phenyl isothiocyanate and from benzophenone anil. They formulate the reaction as follows:



This reaction is discussed further in the section on Anils, Schiff Bases, etc. (*q.v.*).

⁴ Gilman and Furry, *J. Am. Chem. Soc.*, 50, 1214–6 (1928).

⁵ Underwood and Gale, *J. Am. Chem. Soc.*, 56, 2117–20 (1934).

⁶ Schwartz and Johnson, *J. Am. Chem. Soc.*, 53, 1063–8 (1931).

⁷ Young and Roberts, *J. Am. Chem. Soc.*, 68, 649–52 (1946).

⁸ Sachs and Loevy, *Ber.*, 37, 874–8 (1904).

TABLE XIX-I

"NORMAL" REACTIONS OF GRIGNARD REAGENTS WITH ISOCYANATES AND ISOTHIOCYANATES

<u>RMgX</u>	<u>R'NCO or R'NCS</u>	<u>M. P. RCONHR' or RCSNHR'</u>	<u>Ref.</u>
CH ₃ MgCl	C ₆ H ₅ NCO	112-113°	10
CH ₃ MgI	H ₂ C=CHCH ₂ NCS	b. 135-136°/17 mm.	2
CH ₃ MgI	4-ClC ₆ H ₄ NCS	143°	2
CH ₃ MgI	C ₆ H ₅ NCS	75°	1
CH ₃ MgI	4-C ₂ H ₅ OC ₆ H ₄ NCS	99-100°	2
CH ₃ MgI	1-C ₁₀ H ₇ NCO	160°	4
C ₂ H ₅ MgCl	C ₆ H ₅ NCO	104.0-104.5°	10
C ₂ H ₅ MgBr	H ₂ C=CHCH ₂ NCS	b. 136°/12 mm.	2
C ₂ H ₅ MgBr	4-C ₂ H ₅ OC ₆ H ₄ NCS	74-75°	2
C ₂ H ₅ MgBr	1-C ₁₀ H ₇ NCO	126°	4
C ₂ H ₅ MgBr	[—C ₆ H ₄ —4-NCS] ₂	228-229°	2
C ₂ H ₅ MgI	C ₆ H ₅ NCS	67.0-67.5°	1
<i>n</i> -C ₃ H ₇ MgCl	C ₆ H ₅ NCO	91-92°	10
<i>n</i> -C ₃ H ₇ MgBr	C ₆ H ₅ NCO	92°	8
<i>n</i> -C ₃ H ₇ MgBr	C ₆ H ₅ NCS	32-33°	1
<i>n</i> -C ₃ H ₇ MgBr	1-C ₁₀ H ₇ NCO	121°	4
<i>i</i> -C ₃ H ₇ MgCl	C ₆ H ₅ NCO	104.0-104.5°	10
<i>i</i> -C ₃ H ₇ MgBr	C ₆ H ₅ NCO	103°	8
α -Furyl-MgBr	C ₆ H ₅ NCO	121-122°	6
<i>n</i> -C ₄ H ₉ MgCl	C ₆ H ₅ NCO	62-63°	10
<i>n</i> -C ₄ H ₉ MgCl	4-CH ₃ C ₆ H ₄ NCO	72-73°	10
<i>n</i> -C ₄ H ₉ MgCl	1-C ₁₀ H ₇ NCO	109-110°	10
<i>n</i> -C ₄ H ₉ MgBr	C ₆ H ₅ NCO	63°	8
<i>n</i> -C ₄ H ₉ MgBr	1-C ₁₀ H ₇ NCO	112°	4
<i>i</i> -C ₄ H ₉ MgCl	C ₆ H ₅ NCO	109-110°	10
<i>i</i> -C ₄ H ₉ MgCl	4-CH ₃ C ₆ H ₄ NCO	106-107°	10
<i>i</i> -C ₄ H ₉ MgCl	1-C ₁₀ H ₇ NCO	125-126°	10
<i>i</i> -C ₄ H ₉ MgBr	C ₆ H ₅ CNO	109.5°	8

TABLE XIX-I (Continued)

RMgX	R'NCO or R'NCS	M. P. RCONHR' or RCSNHR'	Ref.
<i>i</i> -C ₄ H ₉ MgBr	C ₆ H ₅ CNS	—	1
<i>s</i> -C ₄ H ₉ MgCl	C ₆ H ₅ NCO	105.5–106.5°	10
<i>s</i> -C ₄ H ₉ MgCl	4-CH ₃ C ₆ H ₄ NCO	92.5–93.0°	10
<i>s</i> -C ₄ H ₉ MgCl	1-C ₁₀ H ₇ NCO	128–129°	10
<i>s</i> -C ₄ H ₉ MgBr	C ₆ H ₅ NCO	108°	8
<i>t</i> -C ₄ H ₉ MgCl	C ₆ H ₅ NCO	128°	8
<i>t</i> -C ₄ H ₉ MgCl	C ₆ H ₅ NCO	132–133°	10
<i>t</i> -C ₄ H ₉ MgCl	4-CH ₃ C ₆ H ₄ NCO	119–120°	10
<i>t</i> -C ₄ H ₉ MgCl	1-C ₁₀ H ₇ NCO	146–147°	10
<i>n</i> -C ₅ H ₁₁ MgCl	C ₆ H ₅ NCO	94–95°	10
<i>n</i> -C ₅ H ₁₁ MgCl	4-CH ₃ C ₆ H ₄ NCO	74–75°	10
<i>n</i> -C ₅ H ₁₁ MgBr	C ₆ H ₅ NCO	96°	8
<i>i</i> -C ₅ H ₁₁ MgCl	C ₆ H ₅ NCO	110.0–110.5°	10
<i>i</i> -C ₅ H ₁₁ MgCl	4-CH ₃ C ₆ H ₄ NCO	61.5–62.5°	10
<i>i</i> -C ₅ H ₁₁ MgCl	1-C ₁₀ H ₇ NCO	110–111°	10
<i>i</i> -C ₅ H ₁₁ MgBr	C ₆ H ₅ NCO	108.5°	8
<i>i</i> -C ₅ H ₁₁ MgBr	C ₆ H ₅ NCS	63°	1
CH ₃ (C ₂ H ₅)CHCH ₂ MgBr	C ₆ H ₅ NCO	88°	8
CH ₃ (<i>n</i> -C ₃ H ₇)CHMgCl	C ₆ H ₅ NCO	86–87°	10
CH ₃ (<i>n</i> -C ₃ H ₇)CHMgCl	4-CH ₃ C ₆ H ₄ NCO	107.5–108.5°	10
CH ₃ (<i>n</i> -C ₃ H ₇)CHMgCl	1-C ₁₀ H ₇ NCO	117–118°	10
CH ₃ (<i>n</i> -C ₃ H ₇)CHMgBr	C ₆ H ₅ NCO	88°	8
(C ₂ H ₅) ₂ CHMgCl	C ₆ H ₅ NCO	126–127°	10
(C ₂ H ₅) ₂ CHMgCl	4-CH ₃ C ₆ H ₄ NCO	90–91°	10
(C ₂ H ₅) ₂ CHMgCl	1-C ₁₀ H ₇ NCO	102.5–103.5°	10
(C ₂ H ₅) ₂ CHMgBr	C ₆ H ₅ NCO	123–124°	8
<i>t</i> -C ₅ H ₁₁ MgCl	C ₆ H ₅ NCO	92°	8
<i>t</i> -C ₅ H ₁₁ MgCl	C ₆ H ₅ NCO	90–91°	10
<i>t</i> -C ₅ H ₁₁ MgCl	4-CH ₃ C ₆ H ₄ NCO	83.0–83.5°	10
<i>t</i> -C ₅ H ₁₁ MgCl	1-C ₁₀ H ₇ NCO	137–138°	10

TABLE XIX-I (Continued)

<u>RMgX</u>	<u>R'NCO or R'NCS</u>	<u>M. P. RCONHR' or RCSNHR'</u>	<u>Ref.</u>
C ₆ H ₅ MgBr	CH ₃ NCS	79°	2
C ₆ H ₅ MgBr	H ₂ C=CHCH ₂ NCS	b. 135–136°/17 mm.	2
C ₆ H ₅ MgBr	4-C ₂ H ₅ OC ₆ H ₄ NCS	127°	2
C ₆ H ₅ MgBr	1-C ₁₀ H ₇ NCO	161°	4
C ₂ H ₅ CH=CH(CH ₂) ₂ MgBr	C ₆ H ₅ NCO	87°	11
(CH ₂) ₅ CHMgCl	C ₆ H ₅ NCO	143–144°	10
(CH ₂) ₅ CHMgBr	C ₆ H ₅ NCO	146°	8
(CH ₂) ₅ CHMgBr	1-C ₁₀ H ₇ NCO	188°	4
<i>n</i> -C ₆ H ₁₃ MgBr	C ₆ H ₅ NCO	69°	8
GH ₃ (<i>n</i> -C ₄ H ₉)CHMgCl	C ₆ H ₅ NCO	91–92°	10
4-ClC ₆ H ₄ CH ₂ MgCl	C ₆ H ₅ NCO	165–166°	10
C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ NCO	117°	8
C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ NCO	115–116°	10
C ₆ H ₅ CH ₂ MgCl	1-C ₁₀ H ₇ NCO	166°	4
C ₆ H ₅ CH ₂ MgBr	C ₆ H ₅ NCS	87°	2
4-CH ₃ C ₆ H ₄ MgBr	1-C ₁₀ H ₇ NCO	173°	4
<i>n</i> -C ₃ H ₇ CH=CH(CH ₂) ₂ MgBr	C ₆ H ₅ NCO	100°	11
<i>n</i> -C ₇ H ₁₅ MgBr	C ₆ H ₅ NCO	57°	8
C ₆ H ₅ C≡CMgBr	C ₆ H ₅ NCO	126–127°	3
C ₆ H ₅ CH=CHMgBr	1-C ₁₀ H ₇ NCO	217°	4
C ₆ H ₅ (CH ₂) ₂ MgCl	C ₆ H ₅ NCO	96°	10
CH ₃ [α -furyl-(CH ₂) ₂]CHMgBr	1-C ₁₀ H ₇ MgBr	109.5–110.0°	7
<i>n</i> -C ₄ H ₉ CH=CH(CH ₂) ₂ MgBr	C ₆ H ₅ NCO	95°	11
3,3-Dimethylcyclohexyl-MgBr	1-C ₁₀ H ₇ NCO	204.0–204.5°	12
DL-CH ₃ (<i>n</i> -C ₆ H ₁₃)CHMgBr*	C ₆ H ₅ NCO	72–73°	8
D-CH ₃ (<i>n</i> -C ₆ H ₁₃)CHMgBr†	C ₆ H ₅ NCO	72–73°	8
1-C ₁₀ H ₇ MgBr	1-C ₁₀ H ₇ NCO	236°	4
1-C ₁₀ H ₇ CH ₂ MgCl	C ₆ H ₅ NCO	155°	5
(C ₆ H ₅) ₃ CMgBr	C ₆ H ₅ NCS		9

* From DL-CH₃(*n*-C₆H₁₃)CHBr.† From D-CH₃(*n*-C₆H₁₃)CHBr.

REFERENCES FOR TABLE XIX-I

- (1) Sachs and Loevy, *Ber.*, 36, 585-8 (1903).
- (2) Sachs and Loevy, *Ber.*, 37, 874-8 (1904).
- (3) Johnson and McEwen, *J. Am. Chem. Soc.*, 48, 469-76 (1926).
- (4) Gilman and Furry, *J. Am. Chem. Soc.*, 50, 1214-6 (1928).
- (5) Gilman and Kirby, *J. Am. Chem. Soc.*, 51, 3475-8 (1929).
- (6) Shepard, Winslow, and Johnson, *J. Am. Chem. Soc.*, 52, 2083-90 (1930).
- (7) Gilman and Hickey, *J. Am. Chem. Soc.*, 52, 2144-7 (1930).
- (8) Schwartz and Johnson, *J. Am. Chem. Soc.*, 53, 1063-8 (1931).
- (9) Bachmann and Cockerill, *J. Am. Chem. Soc.*, 55, 2932-4 (1933).
- (10) Underwood and Gale, *J. Am. Chem. Soc.*, 56, 2117-20 (1934).
- (11) Normant, *Compt. rend.*, 226, 1734-6 (1948); *Chem. Abstr.*, 42, 7237 (1948).
- (12) von Doering and Beringer, *J. Am. Chem. Soc.*, 71, 2221-6 (1949).

COMPOUNDS CONTAINING THE GROUPING $\text{—N}=\text{C}<$

Aldimines. Busch⁹ reported that Grignard reagents react additively with benzyldeneaniline, and studied the reaction further with Rinck,¹⁰ extending it to other methyleneimines with Leefhelm.¹¹

In general, addition to methyleneimines of the type $\text{R}'\text{N}=\text{CHR}''$ takes place under relatively mild conditions (*i.e.*, at or below the boiling point of ethyl ether) to give fairly good yields of products which, upon hydrolysis, liberate secondary amines.



A representative preparation is described by Campbell *et al.*¹² "To one mole of *n*-propylmagnesium bromide in 250 ml. of dry ether was added a solution of 66.5 g. (0.5 mole) of benzyldeneethylamine in 50 ml. of dry ether, over a period of one and one-half to two hours; the reaction mixture was refluxed for several hours and allowed to stand overnight. It was hydrolyzed by pouring onto ice and hydrochloric acid."

The authors observe, as a matter of practical interest, that consistently good (60 to 90 percent) yields are obtained when Grignard reagent and base are used in one-to-one molecular ratio only in cases of the more reactive Grignard reagents (*e.g.*, methylmagnesium bromide) and the simplest aldimines (*e.g.*, benzyldenenemethylamine). In other cases a twofold excess of Grignard reagent is recommended. The yields reported in Table XIX-II (reference 11) are for one-to-one reactant ratio, and hence are not in most cases the maximum attainable.

Of the mechanism, or order, of the reaction nothing is known, but it seems probable that additions of this kind are essentially ionic.

⁹ Busch, *Ber.*, 37, 2691-4 (1904).

¹⁰ Busch and Rinck, *Ber.*, 38, 1761-72 (1905).

¹¹ Busch and Leefhelm, *J. prakt. Chem.*, [2], 77, 20-5 (1907).

¹² Campbell, Helbing, Florkowski, and Campbell, *J. Am. Chem. Soc.*, 70, 3868-70 (1948).

TABLE XIX-II

REACTIONS OF GRIGNARD REAGENTS WITH METHYLENEIMINES OF THE TYPE $R'N=CHR''$ (ALDIMINES)

R'	R''	$RMgX$	Yield (%) $R'NHCHRR''$	Ref.
CH ₃	H	C ₆ H ₅ CH ₂ MgCl	—	10
CH ₃	CH ₃	C ₆ H ₅ CH ₂ MgCl	—	10
CH ₃	C ₆ H ₅	CH ₃ MgI	ca. quant.	3
CH ₃	C ₆ H ₅	C ₂ H ₅ MgBr	75	11
CH ₃	C ₆ H ₅	C ₂ H ₅ MgI	—	3
CH ₃	C ₆ H ₅	<i>n</i> -C ₃ H ₇ MgBr	66	11
CH ₃	C ₆ H ₅	<i>i</i> -C ₃ H ₇ MgBr	60	11
CH ₃	C ₆ H ₅	C ₆ H ₅ MgBr	—	3
CH ₃	C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	95	9
CH ₃	2-HOC ₆ H ₄	C ₆ H ₅ CH ₂ MgCl	72	9
CH ₃	3-HOC ₆ H ₄	C ₆ H ₅ CH ₂ MgCl	30	9
CH ₃	4-HOC ₆ H ₄	C ₆ H ₅ CH ₂ MgCl	13	9
CH ₃	3,4-CH ₂ O ₂ C ₆ H ₃	C ₆ H ₅ CH ₂ MgCl	66	9
CH ₃	2-CH ₃ OC ₆ H ₄	C ₆ H ₅ CH ₂ MgCl	78	9
CH ₃	3-CH ₃ OC ₆ H ₄	C ₆ H ₅ CH ₂ MgCl	78	9
CH ₃	2-HO-3-CH ₃ OC ₆ H ₃	C ₆ H ₅ CH ₂ MgCl	53	9
CH ₃	3-CH ₃ O-4-HOC ₆ H ₃	C ₆ H ₅ CH ₂ MgCl	38	9
CH ₃	3-C ₂ H ₅ OC ₆ H ₄	C ₆ H ₅ CH ₂ MgCl	74	9
CH ₃	2,3-(CH ₃ O) ₂ C ₆ H ₃	C ₆ H ₅ CH ₂ MgCl	79	9
CH ₃	3,4-(CH ₃ O) ₂ C ₆ H ₃	C ₆ H ₅ CH ₂ MgCl	52	9
CH ₃	4-(CH ₃) ₂ NC ₆ H ₄	C ₆ H ₅ CH ₂ MgCl	75	9
C ₂ H ₅	C ₆ H ₅	CH ₃ MgI	ca. quant.	3
C ₂ H ₅	C ₆ H ₅	C ₂ H ₅ MgBr	39	11
C ₂ H ₅	C ₆ H ₅	C ₂ H ₅ MgI	—	3
C ₂ H ₅	C ₆ H ₅	<i>n</i> -C ₃ H ₇ MgBr	40	11
C ₂ H ₅	C ₆ H ₅	<i>n</i> -C ₄ H ₉ MgBr	37	11
C ₂ H ₅	C ₆ H ₅	C ₆ H ₅ MgBr	—	3
C ₂ H ₅	C ₆ H ₅	<i>n</i> -C ₄ H ₉ C≡CMgBr	0	11

TABLE XIX-II (Continued)

<u>R'</u>	<u>R''</u>	<u>RMgX</u>	<u>Yield (%) R'NHCHRR''</u>	<u>Ref.</u>
C ₂ H ₅	C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	74	11
C ₂ H ₅	4-CH ₃ OC ₆ H ₄	C ₆ H ₅ CH ₂ MgCl	79	9
HOCH ₂ CH ₂	4-CH ₃ OC ₆ H ₄	C ₆ H ₅ CH ₂ MgCl	79	9
H ₂ C=CHCH ₂	C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	78	9
H ₂ C=CHCH ₂	4-CH ₃ OC ₆ H ₄	C ₆ H ₅ CH ₂ MgCl	86	9
<i>n</i> -C ₃ H ₇	C ₆ H ₅	C ₂ H ₅ MgBr	27	11
<i>n</i> -C ₃ H ₇	C ₆ H ₅	C ₆ H ₅ MgBr	25	11
<i>n</i> -C ₄ H ₉	C ₆ H ₅	C ₂ H ₅ MgBr	30	11
<i>n</i> -C ₄ H ₉	C ₆ H ₅	C ₆ H ₅ MgBr	27	11
C ₆ H ₅	C ₂ H ₅ O	2-CH ₃ C ₆ H ₄ MgBr	55	5
C ₆ H ₅	C ₆ H ₅	CH ₃ MgI	79	1
C ₆ H ₅	C ₆ H ₅	C ₂ H ₅ MgI	—	2
C ₆ H ₅	C ₆ H ₅	<i>n</i> -C ₃ H ₇ MgI	—	2
C ₆ H ₅	C ₆ H ₅	<i>i</i> -C ₅ H ₁₁ MgI	—	2
C ₆ H ₅	C ₆ H ₅	C ₆ H ₅ MgBr	—	2
C ₆ H ₅	C ₆ H ₅	C ₆ H ₅ MgI	—	1
C ₆ H ₅	C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	—	2
C ₆ H ₅	C ₆ H ₅	1-C ₁₀ H ₇ MgBr	—	2
C ₆ H ₅	2-CH ₃ OC ₆ H ₄	CH ₃ MgI	—	4
C ₆ H ₅	2-HO-5-CH ₃ C ₆ H ₃	CH ₃ MgI	—	4
C ₆ H ₅	2-CH ₃ O-5-CH ₃ C ₆ H ₃	CH ₃ MgI	—	4
C ₆ H ₅	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄	CH ₃ MgI	—	2
(CH ₂) ₅ CH	C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	40	9
C ₆ H ₅ CH ₂	C ₆ H ₅	C ₂ H ₅ MgX	—	8
C ₆ H ₅ CH ₂	C ₆ H ₅	C ₆ H ₅ MgX	—	8
C ₆ H ₅ CH ₂	C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	53	9
C ₆ H ₅ CH ₂	4-HOC ₆ H ₄	C ₆ H ₅ CH ₂ MgCl	52	9
C ₆ H ₅ CH ₂	4-CH ₃ C ₆ H ₄	C ₂ H ₅ MgX	—	8
C ₆ H ₅ CH ₂	4-CH ₃ OC ₆ H ₄	C ₂ H ₅ MgX	—	8

TABLE XIX-II (Continued)

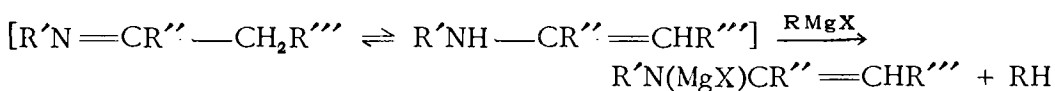
<u>R'</u>	<u>R''</u>	<u>RMgX</u>	<u>Yield (%) R'NHCHRR''</u>	<u>Ref.</u>
2-CH ₃ C ₆ H ₄	C ₆ H ₅	C ₆ H ₅ MgBr	—	2
4-CH ₃ C ₆ H ₄	C ₆ H ₅	C ₆ H ₅ MgBr	—	2
2-CH ₃ OC ₆ H ₄	C ₆ H ₅	C ₆ H ₅ MgBr	—	2
4-CH ₃ OC ₆ H ₄	C ₆ H ₅	C ₆ H ₅ MgBr	—	2
2-C ₁₀ H ₇	C ₆ H ₅	2-C ₆ H ₅ C ₆ H ₄ MgI	7	12
C ₆ H ₅ (C ₆ H ₅ CO)C=C(C ₆ H ₅)	H	CH ₃ MgI	—	7
C ₆ H ₅ (C ₆ H ₅ CO)C=C(C ₆ H ₅)	H	C ₆ H ₅ MgBr	—	6
C ₆ H ₅ (C ₆ H ₅ CO)C≡C(C ₆ H ₅)	CH ₃	CH ₃ MgI	—	7

REFERENCES FOR TABLE XIX-II

- (1) Busch, *Ber.*, 37, 2691-4 (1904).
- (2) Busch and Rinck, *Ber.*, 38, 1761-72 (1905).
- (3) Leefhelm, *J. prakt. Chem.*, [2], 77, 20-5 (1907).
- (4) Anselmino, *Ber.*, 40, 3465-74 (1907).
- (5) Gatterman, *Ann.*, 393, 215-34 (1912).
- (6) Kohler and Blatt, *J. Am. Chem. Soc.*, 50, 1217-26 (1928).
- (7) Kohler and Richtmyer, *J. Am. Chem. Soc.*, 50, 3092-106 (1928).
- (8) Grammaticakis, *Compt. rend.*, 207, 1224-5 (1938); *Chem. Abstr.*, 33, 2494 (1939).
- (9) Moffett and Hoehn, *J. Am. Chem. Soc.*, 69, 1792-4 (1947).
- (10) Evdokimoff, *Gazz. chim. ital.*, 77, 318-26 (1947); *Chem. Abstr.*, 42, 2586 (1948).
- (11) Campbell, Helbing, Florkowski, and Campbell, *J. Am. Chem. Soc.*, 70, 3868-70 (1948).
- (12) Gilman and Morton, *J. Am. Chem. Soc.*, 70, 2514-5 (1948).

The relatively unreactive *n*-butylethynylmagnesium bromide did not undergo addition; the only product isolated appeared to be a dimer ($C_{18}H_{22}N_2$) of the original base (benzylideneethylamine). Knowledge of the constitution of this "dimer" might throw some light on the reaction mechanism.

Ketimines. When the hydrogen atom of $R'N=CHR''$ is replaced by an alkyl or aryl group the "normal" addition reaction does not take place.¹³ Aliphatic or aliphatic-aromatic ketoanils react as though they existed in the tautomeric enamic form.¹⁴



This statement should not be interpreted as necessarily implying that only the enamic form reacts. There may well be a Grignard reagent enamination of ketimines similar to the analogous Grignard reagent enolization of ketones (*q.v.*, Chapter VI). There is, however, spectroscopic evidence to indicate that some ketoanils, at least, exist largely in the enamic form.¹⁵

Plancher and Ravenna¹⁶ had obtained from the interaction of acetophenone anil and phenylmagnesium bromide a product (admittedly impure) which they believed to have the empirical formula $C_{20}H_{19}N$, corresponding to that of an addition product, $CH_3(C_6H_5)_2CNHC_6H_5$. Operating under the conditions described by Plancher and Ravenna, however, Short and Watt (*loc. cit.*^{14a}) isolated, together with a little aniline, a product of the em-

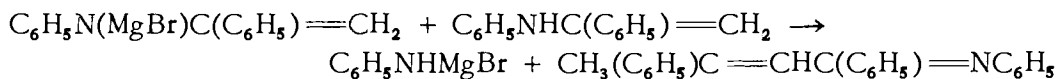
¹³See, e.g., Grammaticakis, *Compt. rend.*, 223, 804-6 (1946); *Chem. Abstr.*, 41, 1602 (1947).

¹⁴See, e.g., (a) Short and Watt, *J. Chem. Soc.*, 1930, 2293-7; (b) Montagne, *Compt. rend.*, 199, 671-3 (1934); *Chem. Abstr.*, 29, 465 (1934).

¹⁵von Auwers and Susseml, *Ber.*, 63B, 1072-86 (1930).

¹⁶Plancher and Ravenna, *Atti accad. Lincei*, [5], 15, II, 555-61 (1906); *Chem. Zentr.*, 1907, I, 111.

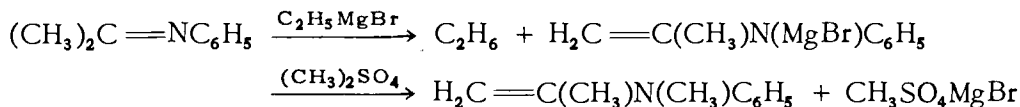
pirical formula $C_{22}H_{19}N$ which they satisfactorily identified as dypnone anil. The reaction, therefore, has the appearance of a cleavage-condensation which may be represented stoichiometrically (without prejudice regarding mechanism) as follows:



When the complicating presence of benzene in the hydrolysis product was avoided by the use of ethylmagnesium bromide, dypnone anil was isolated in 81 percent yield.

Short and Watt (*loc. cit.*^{14a}) also investigated some of the Grignard reactions of acetone anil. With excess methylmagnesium bromide in amyl ether they observed methane evolution corresponding to 0.94 equivalent of "active" hydrogen.

When the anil was treated successively with ethylmagnesium bromide and methyl sulfate, *N*-methyl-*N*-isopropenylaniline was obtained in fairly good yield (9 g. of amine from 13 g. of anil).

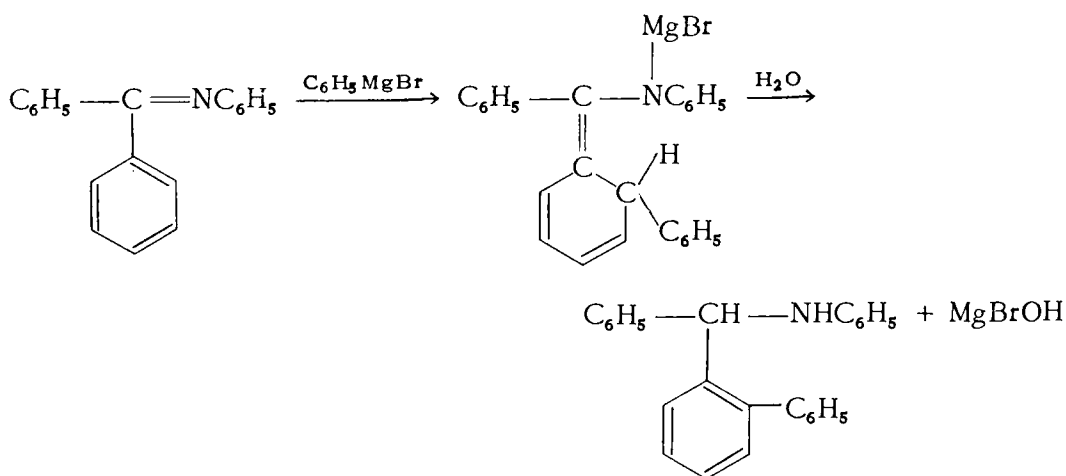


When phenylmagnesium bromide was employed, benzene, together with some aniline, was isolated. The presence of aniline among the reaction products indicates that acetone anil, like acetophenone anil, undergoes some cleavage. If cleavage is indeed concomitant to condensation, and if the reaction involves one molecule (or ion-pair) of enamine and one molecule of anil (or enamine), as heretofore suggested, it would appear that chances of isolating the condensation product would be best when one equivalent of Grignard reagent is added to two equivalents of anil, and when the Grignard reagent selected is such as to yield a gaseous or easily volatile product in the initial enaminization step.

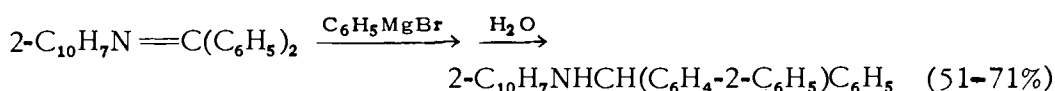
Although benzophenone anil appears to react vigorously with methylmagnesium bromide in ethyl ether (heat effect), practically quantitative recovery of the anil can be achieved upon hydrolysis of the resultant precipitate (Short and Watt, *loc. cit.*^{14a}). Whereas there is here no possibility of enaminization, and no gas evolution is observed, the interaction must consist in Werner complex formation analogous to that observed with dimethylaniline, for example.

When benzophenone anil is refluxed with phenylmagnesium bromide in ether-toluene solution at 70–80° for six to eight hours, the major isolable product (42 percent yield) is the result of an addition, but is not the triphenylmethylaniline which would be expected to result from "normal" addition of the Grignard reagent at the carbon-nitrogen double bond.¹⁷ Formally, at least, the reaction is a 1,4-addition.

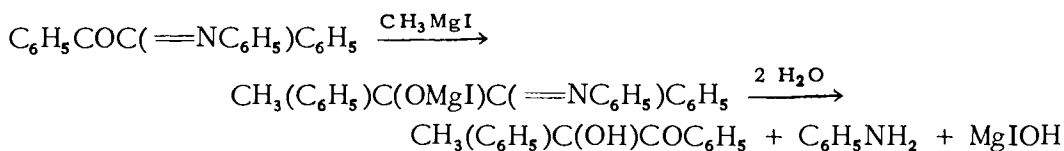
¹⁷Gilman, Kirby, and Kinney, *J. Am. Chem. Soc.*, 51, 2252–61 (1929).



A similar 1,4-addition has been observed in the case of the corresponding *N*-2-naphthyl compound.¹⁸



It is reported¹⁹ that the monoanil of benzil, on prolonged heating with a large excess of methylmagnesium iodide, gives α -methylbenzoïn in good yield. This has the appearance of a normal addition at the carbonyl double bond, (followed by hydrolysis), but may be more complicated.



With ethylmagnesium bromide or iodide or with phenylmagnesium bromide a similar reaction does not occur; the products are benzanilide, benzoic acid, aniline, and benzil (Montagne and Garry, *loc. cit.*¹⁹).

The dianil of biacetyl is said to undergo "normal" addition with one equivalent of methylmagnesium iodide, ethylmagnesium bromide, *n*-butylmagnesium bromide,²⁰ or benzylmagnesium chloride²¹ in ether solution.



The reaction with *t*-butylmagnesium chloride yields a product of empirical formula $\text{C}_{20}\text{H}_{26}\text{N}_2$ also believed to have the structure resulting from "normal" addition.²² In contradiction of an earlier report, it is stated that

¹⁸ Gilman and Morton, *J. Am. Chem. Soc.*, 70, 2514-5 (1948).

¹⁹ Montagne and Garry, *Compt. rend.*, 204, 1659-61 (1937); *Chem. Abstr.*, 31, 6223 (1937).

²⁰ Garry, *Ann. chim.*, [11], 17, 5-99 (1942).

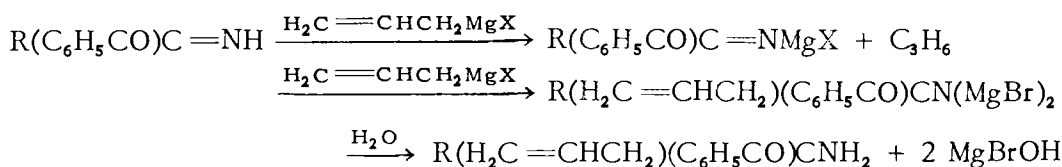
²¹ Montagne and Garry, *Compt. rend.*, 208, 1734-7 (1939); *Chem. Zentr.*, 1940, I, 859.

²² Roch-Garry, *Bull. soc. chim.*, [5], 14, 450-3 (1947).

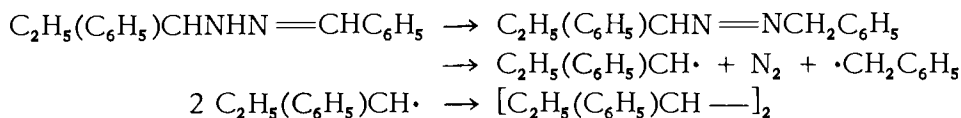
the dianil of benzil also undergoes "normal" addition with one equivalent of methylmagnesium iodide, as well as with ethylmagnesium iodide (Garry, *loc. cit.*²⁰).

When reactions of biacetyl dianil with methylmagnesium iodide, ethylmagnesium bromide, or *n*-butylmagnesium bromide are conducted in boiling benzene, "normal" additions of two equivalents of Grignard reagent take place (Garry, *loc. cit.*²⁰).

Ketimines of the type $R'R''C=NH$ apparently suffer no inhibition of the "normal" addition. At any rate it is reported by Rehberg and Henze²³ that methyl- and ethylphenacylcarbinimines add allylmagnesium halides to form the corresponding alkylallylphenacylcarbinamines in 85 and 89 percent yields respectively.



Aldazines. Franzen and Deibel²⁴ report that, when treated with two equivalents of ethylmagnesium bromide, benzaldazine $[(C_6H_5CH=N-)_2]$ is reduced to benzylbenzylidenehydrazine $(C_6H_5CH_2NHN=CHC_6H_5)$. This observation has been confirmed by Busch and Fleischman,²⁵ who observed further that when a considerable excess (*ca.* four equivalents) of Grignard reagent is used, 3,4-diphenylhexane is isolable (in addition to the reduced base). The hydrocarbon is regarded as resulting from decomposition of the presumably unstable monoaddition product.



When benzaldazine was treated with phenylmagnesium bromide the products isolated were benzylbenzylidenehydrazine, benzhydrylbenzylidenehydrazine, and benzhydrylhydrazine (possibly a hydrolysis fragment of the "normal" monoaddition product).

Benzylmagnesium chloride, with benzaldazine, formed the "normal" addition product $[C_6H_5(C_6H_5CH_2)CHNHN=CHC_6H_5]$ and *sym.*-dibenzylhydrazine.

From the reaction of anisaldazine with benzylmagnesium chloride the "normal" addition product $[4-CH_3OC_6H_4(C_6H_5CH_2)CHNHN=CHC_6H_4-4-OCH_3]$ was isolated in two (presumably stereoisomeric) forms.

According to Bretschneider *et al.*,²⁶ anisaldazine, treated with an excess of ethylmagnesium bromide yields a nitrogenous intermediate (m. 76–78°), characterized as $[C_2H_5(4-CH_3OC_6H_4)CHNH-]_2$, which upon

²³ Rehberg and Henze, *J. Am. Chem. Soc.*, 63, 2785–9 (1941).

²⁴ Franzen and Deibel, *Ber.*, 38, 2716–8 (1905).

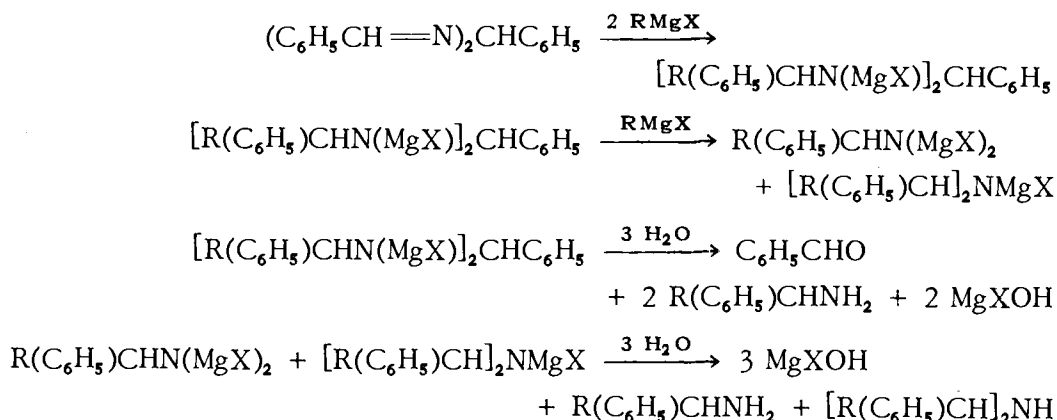
²⁵ Busch and Fleischman, *Ber.*, 43, 740–50 (1910).

²⁶ Bretschneider, Jonge-Bretschneider, and Ajtai, *Ber.*, 74B, 571–88 (1941).

thermal decomposition loses nitrogen to form a mixture (m. 144°) of the meso (m. $186-187^{\circ}$) and racemic (m. $126-128^{\circ}$) forms of the dimethyl ether of hexestrol.*

The nature of the incidental reduction reactions reported is not clear. A reduction of an aldazine by ethylmagnesium bromide analogous to the ketonic reductions by alkyl Grignard reagents (*q.v.*, Chapter VI) is, of course, conceivable, but such a reduction could not be effected by a benzylmagnesium halide. A reduction analogous to that of the azo compounds (*q.v.*) seems improbable. A magnesious halide reduction brought about by the presence of excess metallic magnesium also appears improbable, and in any case could not occur when the halide employed is a chloride. The reaction invites further study, with note taken of the presence or absence of stilbene and/or bibenzyl, and of the effect of metallic impurities.

Hydramides. According to Busch and Leefhelm,²⁷ hydrobenzamide $[(C_6H_5CH=N)_2CHC_6H_5]$, when treated with an excess of alkyl or aralkyl Grignard reagent (CH_3MgI , C_2H_5MgI , $n-C_3H_7MgI$, $C_6H_5CH_2MgCl$), and then, after ether distillation, heated on a water-bath to frothing, yields a product from which, upon hydrolysis, benzaldehyde, primary amine, and secondary amine may be recovered in various proportions, depending upon the details of experimental procedure. Comparative studies with ethylmagnesium iodide indicate that excess Grignard reagent, together with vigorous (oil-bath) and prolonged heat-treatment, favors the production of secondary amine at the expense of benzaldehyde and primary amine. The reaction is visualized by Busch and Leefhelm as follows:



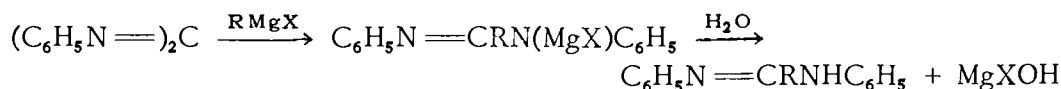
When α -naphthylmagnesium bromide is used the products are primary amine $[C_6H_5(1-C_{10}H_7)CHNH_2]$ and isoämarine (2-phenyl-4,5-*trans*-diphenyl-4,5-dihydroimidazole). The formation of isoämarine is interesting, for it suggests a type of reduction similar to that undergone by the azo compounds (*q.v.*), in which case bi- α -naphthyl would be a probable reaction product.

* Undoubtedly a preliminary atmospheric oxidation of the hydrazo to the azo compound is here involved.

²⁷ Busch and Leefhelm, *J. prakt. Chem.*, [2], 77, 1-20 (1907).

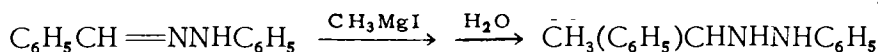
Anishydramide $[(4\text{-CH}_3\text{OC}_6\text{H}_4\text{CH}=\text{N})_2\text{CHC}_6\text{H}_5]$, with methyl- and ethylmagnesium iodides and phenylmagnesium bromide, yielded primary amines $[\text{R}(4\text{-CH}_3\text{OC}_6\text{H}_4)\text{CHNH}_2]$.

Carbodiimides. According to Busch and Hobein,²⁸ carbodiphenylimide $[(\text{C}_6\text{H}_5\text{N}=\text{})_2\text{C}]$ undergoes "normal" monoaddition with Grignard reagents.

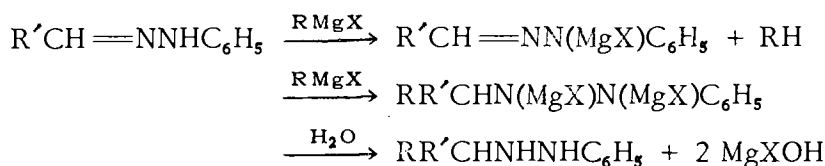


The following Grignard reagents are reported to give the addition product in the percentage yields indicated: methylmagnesium iodide (*ca.* 65), phenylmagnesium bromide (>70), benzylmagnesium chloride (40), α -naphthylmagnesium bromide (60).

Phenylhydrazones and osazones. Busch and Rinck²⁹ report that the phenylhydrazone of benzaldehyde forms an addition product with methylmagnesium iodide.



It would appear that the "normal" addition at the carbon-nitrogen double bond is characteristic of the simple phenylhydrazones of aldehydes.³⁰ Although the present authors have encountered in the literature no statement pro or con, it seems probable that the initial reaction is the replacement of "active" hydrogen, which is then followed by addition.



In addition to a "good yield" of the "normal" product, the reaction between benzaldehyde phenylhydrazone and ethylmagnesium bromide is reported to produce aniline, α -phenylpropylamine, and propiophenone (Grammaticakis, *loc. cit.*^{30a}). Symmetrically substituted phenylhydrazines of the type produced by "normal" addition are highly susceptible to "autoxidation" (*cf.* Grammaticakis, *loc. cit.*^{30b}).



and it seems highly probable that the corresponding halomagnesium intermediates would be similarly oxygen-sensitive. Propiophenone is therefore readily accounted for as a hydrolysis fragment of a secondary oxidation product. Aniline and α -phenylpropylamine obviously result from reductive cleavage of the addition product, but whether this is a true Grignard reagent reduction or the consequence of hydrolysis in the presence of residual magnesium is not apparent from the available data.

²⁸ Busch and Hobein, *Ber.*, 40, 4296-8 (1907).

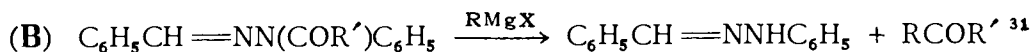
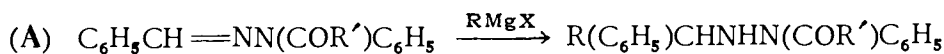
²⁹ Busch and Rinck, *Ber.*, 38, 1761-72 (1905).

³⁰ Grammaticakis, (a) *Compt. rend.*, 202, 1289-91 (1936); *Chem. Abstr.*, 30, 4156 (1936); (b) *Compt. rend.*, 204, 1262-3 (1937); *Chem. Abstr.*, 31, 4954 (1937); (c) *Compt. rend.*, 208, 287-9 (1939); *Chem. Abstr.*, 33, 3778 (1939).

Other secondary products of similar reactions (*cf.* Grammaticakis, *loc. cit.*^{30c}) are imines, which are presumed to result from decomposition of the primary addition products.



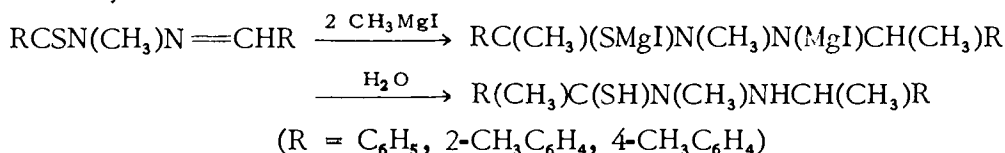
The principal reactions of Grignard reagents with *N*-acylphenylhydrazones of benzaldehyde are said to be:



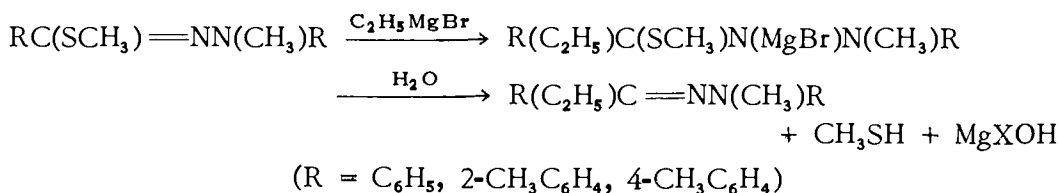
The *N*-acetyl derivative reacts chiefly according to **A** with ethylmagnesium bromide, but almost exclusively according to **B** with methylmagnesium iodide. With phenylmagnesium bromide the primary reaction is B, and in the presence of excess Grignard reagent *sym.*-phenylbenzhydrylhydrazine, benzophenone phenylhydrazone, benzophenone anil, benzophenone imine, aniline, and *sym.*-tetraphenylethane are formed as secondary products.

The *N*-benzoyl and *N*-phenylcarbamyl derivatives undergo chiefly the "normal" addition reaction (A) with methylmagnesium iodide and ethyl- and phenylmagnesium bromides.

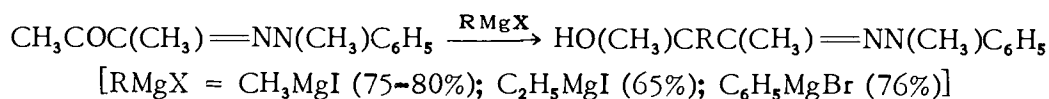
According to Wuyts and Lacourt,³² thioacylated hydrazones also react additively.



The *S*-methylated thiohydrazides probably react additively in propyl ether also although the overall reaction has the appearance of a metathetical exchange.³³



Diels *et al.*³⁴ report carbonyl double-bond addition (in preference to $N=C$ double-bond addition) to *N*-methyl biacetyl phenylhydrazone to the extent of 65–80 percent.



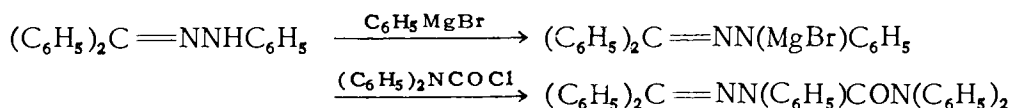
³¹ Grammaticakis, *Compt. rend.*, 208, 1910–2 (1939); *Chem. Zentr.*, 1940, II, 335; *Chem. Abstr.*, 33, 7287 (1939).

³² Wuyts and Lacourt, *Bull. soc. chim. Belg.*, 45, 445–53 (1936).

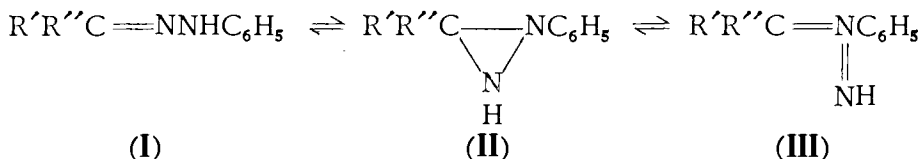
³³ Wuyts and Lacourt, *Bull. soc. chim. Belg.*, 44, 395–410 (1935).

³⁴ Diels and ter Meer, *Ber.*, 42, 1940–5 (1909); Diels and Johlin, *ibid.*, 44, 403–10 (1911).

The phenylhydrazones of ketones appear to be more or less sterically inhibited so far as "normal" addition of a Grignard reagent at the carbon-nitrogen double bond is concerned.³⁵ That active hydrogen is replaced was shown by Gilman *et al.*,³⁶ who treated benzophenone phenylhydrazone successively with phenylmagnesium bromide and diphenylcarbonyl chloride, thus obtaining the corresponding semicarbazide.

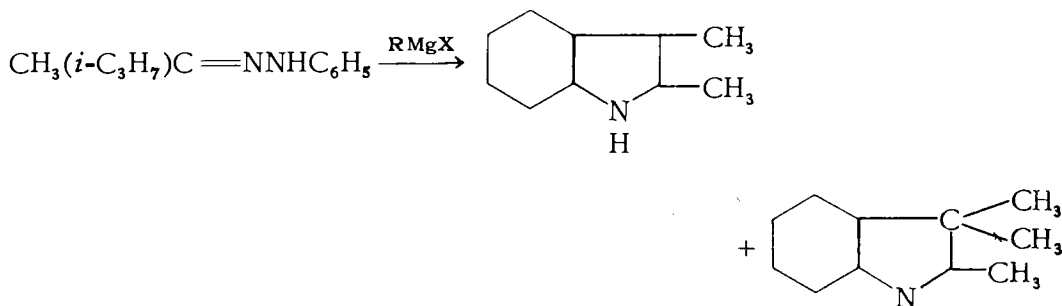
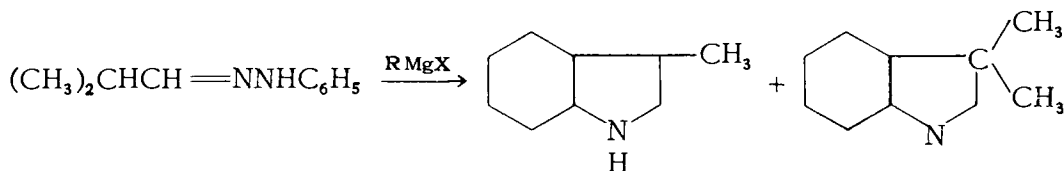


Grammaticakis³⁷ reports benzophenone anil, together with a little benzophenone, aniline, and ammonia, as the principle product of reaction (presumably "forced") between benzophenone phenylhydrazone and ethylmagnesium bromide. Under similar treatment acetophenone and acetone phenylhydrazones yield α -phenyl- and α -methylindoles respectively. To account for the products observed, Grammaticakis proposes an equilibrium between isomeric forms of the hydrazone.



It is then postulated that form **III** (after "active" hydrogen replacement) undergoes an unusual series of reactions which does some violence to the ordinary concepts of valence.

Other cyclization reactions of phenylhydrazones reported by Grammaticakis³⁸ are as follows.

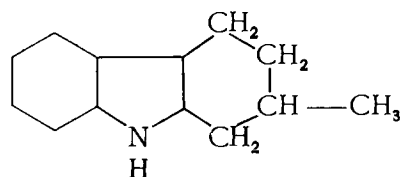
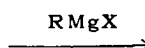
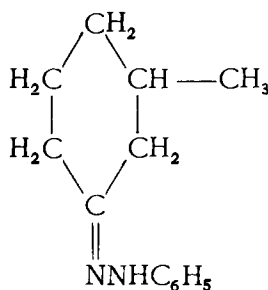
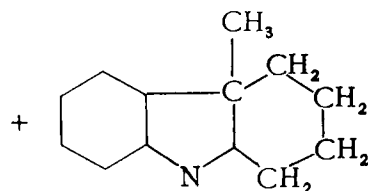
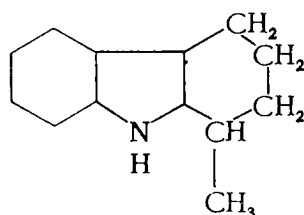
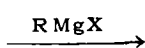
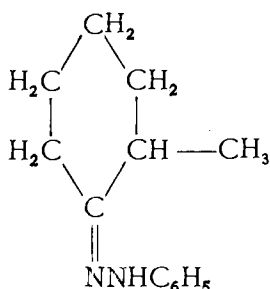
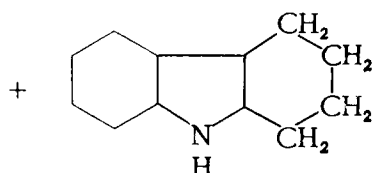
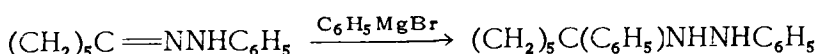
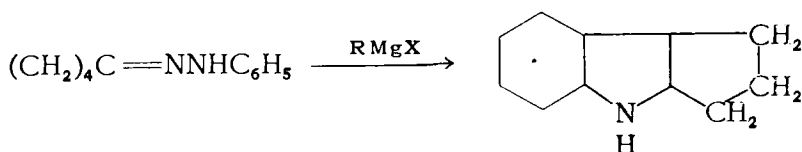


³⁵See, e.g.: Grammaticakis, *Compt. rend.*, 223, 804-6 (1946); *Chem. Abstr.*, 41, 1602 (1947).

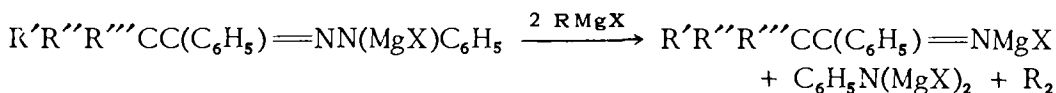
³⁶Coleman, Gilman, Adams, and Pratt, *J. Org. Chem.*, 3, 99-107 (1938).

³⁷Grammaticakis, *Compt. rend.*, 204, 502-4 (1937); *Chem. Abstr.*, 31, 3460 (1937).

³⁸Grammaticakis, (a) *Compt. rend.*, 209, 317-9 (1939); *Chem. Abstr.*, 34, 100 (1940); (b) *Compt. rend.*, 210, 569-72 (1940); *Chem. Abstr.*, 34, 3986 (1940).



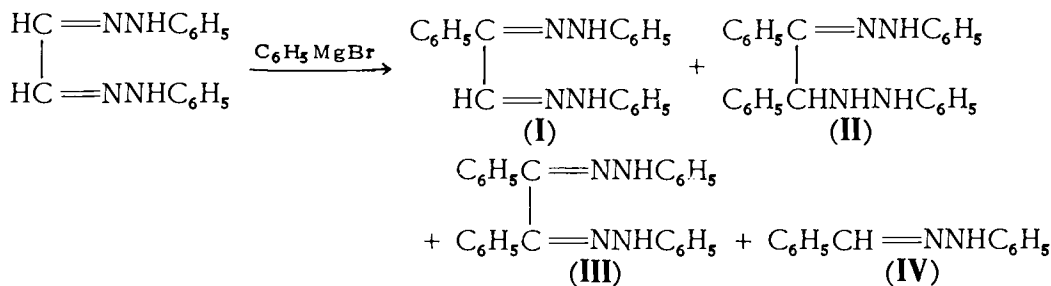
According to Grammaticakis,³⁹ trimethyl-, *n*-butyldimethyl-, and benzyl-dimethylacetophenone phenylhydrazones, when treated at 116–180° for twelve to seventeen hours, with methylmagnesium iodide or ethylmagnesium bromide, all yield the corresponding imines and anils, together with aniline. It is suggested that imine formation takes place as follows:



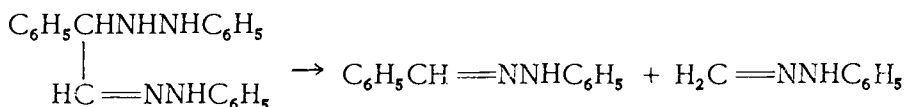
The phenylosazone of glyoxal is reported⁴⁰ to undergo both mono- and di-addition with phenylmagnesium bromide.

³⁹Grammaticakis, *Compt. rend.*, 206, 1307–9 (1938); *Chem. Abstr.*, 32, 5798 (1938).

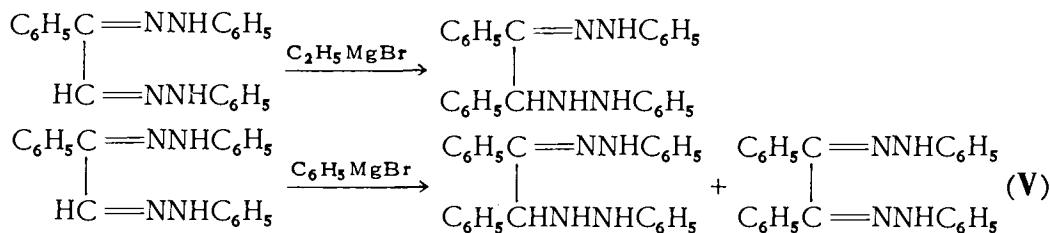
⁴⁰Grammaticakis, *Compt. rend.*, 208, 1998–2000 (1939); *Chem. Abstr.*, 33, 7285 (1939).



Compounds **I**, **II**, and **III** must all result from autoxidation of the addition products, which are highly oxygen-sensitive. *sym.*-Benzylidenephénylhydrazine (**IV**) may be a cleavage-rearrangement fragment of the mono-addition product.



Strangely enough it is said that the phenylosazone of phenylglyoxal does not react with methylmagnesium iodide, although it is reported to yield mono-addition products with both ethyl- and phenylmagnesium bromides (Grammaticakis, *loc. cit.*⁴⁰).



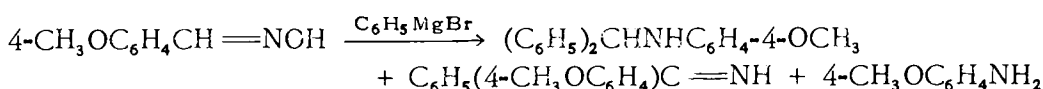
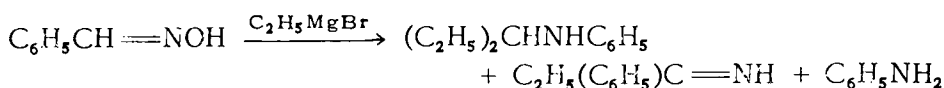
The phenylosazone of diphenylglyoxal (**V**) does not condense with methylmagnesium iodide or ethyl- or phenylmagnesium bromides, even when the reaction mixtures are heated for as long as fourteen hours (Grammaticakis, *loc. cit.*⁴⁰).

Oximes and isonitroso compounds. The oximes do not react readily (except as "active hydrogen" compounds) with Grignard reagents in ether solution. All other reactions reported have been carried out under more or less "forced" conditions. For example, Busch and Hobein⁴¹ distilled most of the ether from a solution of phenylmagnesium bromide, and then made portionwise addition of α -benzaloxime to the warm residual paste. The heat of "active" hydrogen replacement was then sufficient to effect condensation, with the production of *N*-benzhydrylaniline. When the methyl or benzyl ethers of α -benzaloxime were used, condensation was effected by oil-bath heating, with formation of the same product.

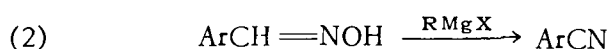
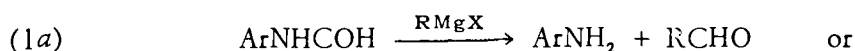
When α -benzaloxime and its methyl ether were treated analogously with α -naphthylmagnesium bromide, the product isolated was α -naphthylamine.

⁴¹ Busch and Hobein, *Ber.*, 40, 2096-9 (1907).

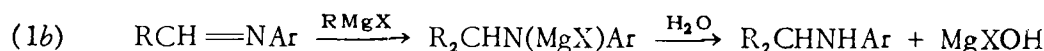
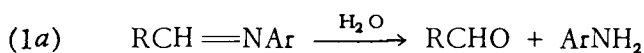
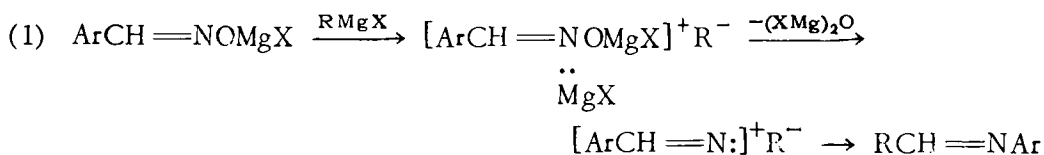
Grammaticakis⁴² treated benzaldoxime with a large excess (6–10 equiv.) of ethylmagnesium bromide and obtained *N*-3-pentylaniline, together with 1-imino-1-phenylpropane and aniline. Analogous products were obtained when anisaldoxime was treated with excess ethylmagnesium bromide, or with phenylmagnesium bromide.



Grammaticakis (*loc. cit.*⁴²) proposes that aryl aldioximes react with Grignard reagents in the following ways:



It scarcely seems necessary to postulate an *N*-arylated formamide as an intermediate, although some rearrangement of the Beckmann type is indicated by the major product of the reaction of benzaldoxime with ethylmagnesium bromide, for instance. Following a scheme suggested to account for the acid-catalyzed Beckmann rearrangement of oximes,⁴³ one might substitute for the first series of reactions above proposed:



Stieglitz and Maver⁴⁴ attempted the preparation of a hydroxylamine derivative by treating acetophenone oxime with phenylmagnesium bromide in the hope of effecting a "normal" addition at the carbon-nitrogen double bond, and at first believed that they had succeeded. It was subsequently found (Stieglitz and Cole⁴⁵), however, that the product of this reaction is

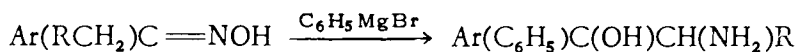
⁴²Grammaticakis, *Compt. rend.*, 210, 716–8 (1940); *Chem. Abstr.*, 34, 5062 (1940).

⁴³See, e.g.: Wallis, Gilman's "Organic Chemistry," John Wiley and Sons, Inc., New York, 2nd edition, 1943, p. 984.

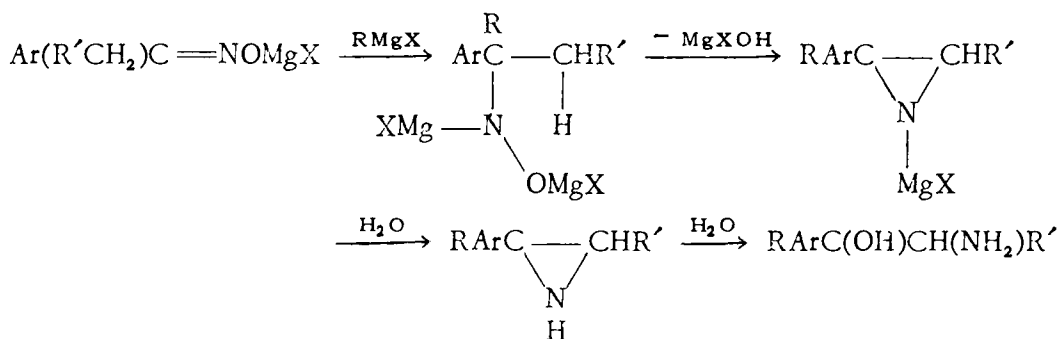
⁴⁴Maver, Dissertation, University of Chicago, 1926.

⁴⁵Cole, Dissertation, University of Chicago, 1929.

in fact 1,1-diphenyl-2-aminoethanol. The similar reactions of propiophenone and desoxybenzoïn oximes were studied (under Stieglitz) by Sturgeon⁴⁶ and Campbell,⁴⁷ respectively, and analogous products were obtained. Similar results are reported by Campbell *et al.*⁴⁸



Campbell (*loc. cit.*⁴⁷) had suggested, without at the time being able to offer proof, that the rather unusual nitrogen rearrangement involved takes place through ethyleneimine formation. Hoch,⁴⁹ however, isolated both 1,1-diphenyl-1,2-iminopropane and 1,1-diphenyl-2-aminopropanol as products of the reaction of propiophenone oxime with phenylmagnesium bromide. When ethylmagnesium bromide was used, the ethyleneimine (2,3-imino-3-phenylpentane) was the sole product. Campbell *et al.*⁵⁰ subsequently showed that the product obtained depends principally on the method of isolation. When the reaction mixture is hydrolyzed at low temperature (*ca.* 0°) with dilute hydrochloric acid, or, better still, iced ammonium chloride solution, the ethyleneimine is obtained; when hydrolysis is carried out at higher temperatures with strongly acidic solutions the amino alcohol is obtained.



Campbell⁵¹ has also shown that the aliphatic Grignard reagents are similar in their behavior to the aryl reagents.

When R'CH₂ is replaced by an aryl or tertiary alkyl group this type of reaction is, of course, impossible. According to Hoch⁵² the principal reaction in such cases is usually a reduction of the oxime to the imine, which may be isolated as such or as the corresponding ketone, depending upon experimental conditions. The mechanism of the reduction is unknown, but the stoichiometric requirements would be met by some such scheme as the following:

⁴⁶ Sturgeon, Dissertation, University of Chicago, 1929.

⁴⁷ Campbell, Dissertation, University of Chicago, 1932.

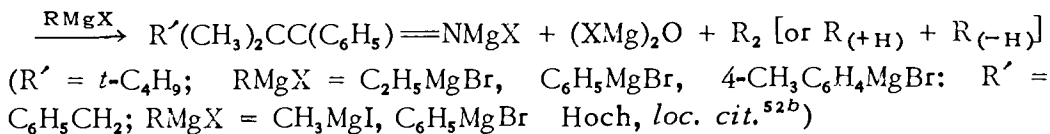
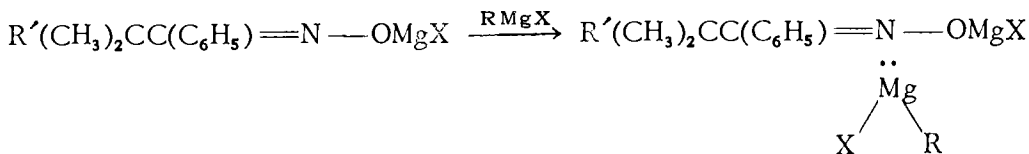
⁴⁸ (a) Campbell and McKenna, *J. Org. Chem.*, 4, 198-205 (1939); (b) Campbell, Campbell, and Chaput, *ibid.*, 8, 99-102 (1943).

⁴⁹ Hoch, *Compt. rend.*, 198, 1865-8 (1934); *Chem. Abstr.*, 28, 4711 (1934).

⁵⁰ Campbell, Campbell, McKenna, and Chaput, *J. Org. Chem.*, 8, 103-9 (1943).

⁵¹ Campbell, Campbell, Hess, and Schaffner, *J. Org. Chem.*, 9, 184-6 (1944).

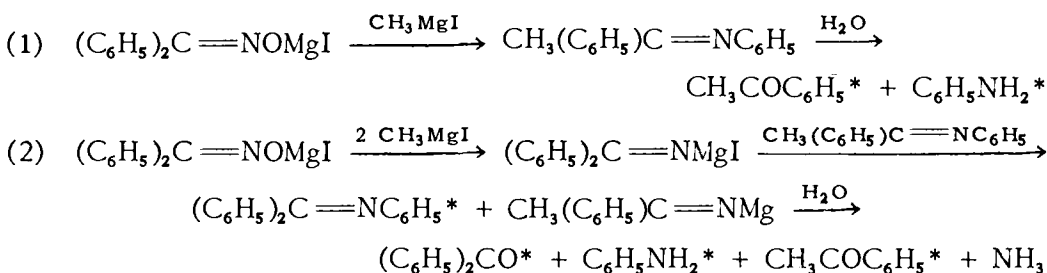
⁵² Hoch (a) *Compt. rend.*, 203, 799-801 (1936); *Chem. Abstr.*, 31, 1786 (1937); (b) *Compt. rend.*, 204, 358-60 (1937); *Chem. Abstr.*, 31, 3026 (1937).



From the products of a similar reduction of diphenylhydroxylamine by phenylmagnesium bromide, Gilman and McCracken⁵³ were able to isolate 71 percent of the theoretical yield of biphenyl. The amount of phenol detectable did not exceed that in a blank control experiment.

Products isolated in some other experiments indicate that a rearrangement of the Beckman type may compete with the simple reduction. However, it is scarcely necessary to assume, as Hoch (*loc. cit.*^{52a}) has done, that benzanilide is an intermediate in the reaction of benzophenone oxime with methylmagnesium iodide. A scheme similar to that suggested for the benzaldoxime rearrangement would suffice to account for the acetophenone and aniline isolated after hydrolysis. The trace of benzophenone anil detected might well result from exchange of the imine with acetophenone anil rather than from reaction with the free aniline which would result from reaction of benzanilide with the Grignard reagent. Moreover, it is difficult to see how acetophenone could survive as such in the presence of excess Grignard reagent.

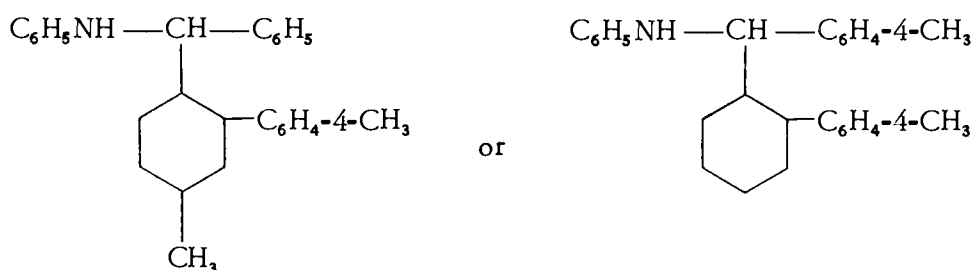
Revised in accordance with the foregoing comments, Hoch's reaction scheme becomes:



The products starred were isolated by Hoch. In addition he obtained an unidentified base to which he assigned the empirical formula $(C_{14}H_{11}N)_2$.

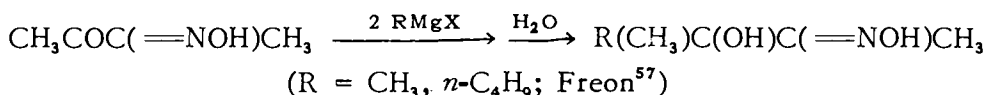
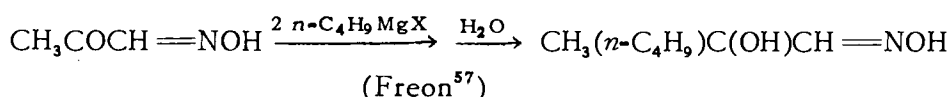
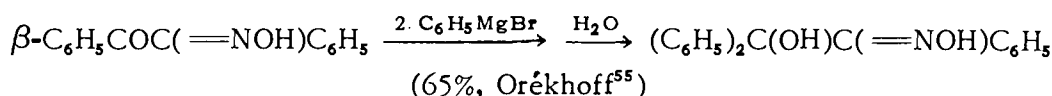
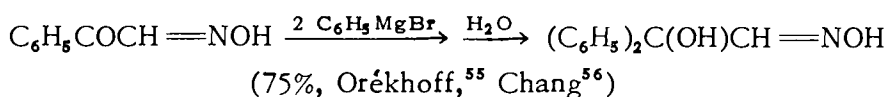
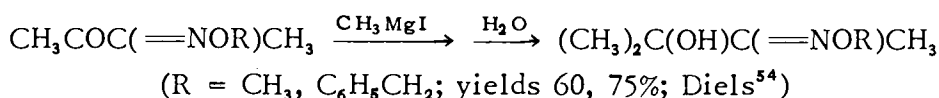
A similar Beckmann-type rearrangement would make benzophenone anil an intermediate in the reaction of phenylmagnesium bromide with benzophenone oxime, and would thus account for the *o*-phenylbenzhydrylaniline isolated by Hoch (*loc. cit.*^{52a}). (*Cf.* Gilman *et al.*, *loc. cit.*⁵³) It is perhaps unfortunate that no one has seen fit to carry out this reaction with an aryl Grignard reagent other than phenylmagnesium bromide. With *p*-tolylmagnesium bromide, for example, the product should be

⁵³ Gilman and McCracken, *J. Am. Chem. Soc.*, 49, 1052-61 (1927).



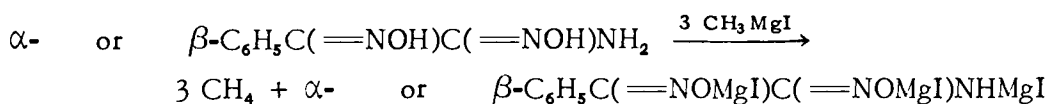
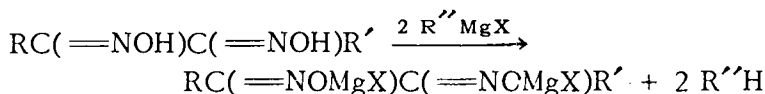
or a mixture of the two.

As might be expected, under mild reaction conditions the isonitroso compounds react as ketones (as well as "active" hydrogen compounds). Some typical reactions reported are as follows.



Isonitrosocamphor is reported (Forster⁵⁸) to yield with methylmagnesium iodide a compound of the empirical formula C₁₁H₁₉O₂N (m. 180°), and isonitrosothiocamphor with the same Grignard reagent (Sen⁵⁹), an orange liquid of empirical formula C₁₁H₁₇NS.

Under mild conditions dioximes react as "active" hydrogen compounds (Longo⁶⁰).



⁵⁴Diels and ter Meer, *Ber.*, 42, 1940-5 (1909).

⁵⁵Orékhoff and Tiffeneau, *Bull. soc. chim.*, [4], 41, 839-43 (1927).

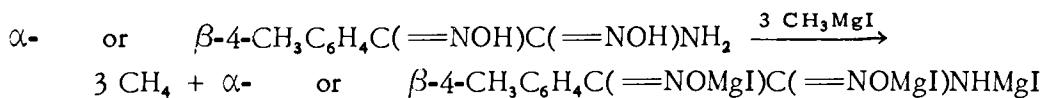
⁵⁶Chang and Tseng, *Trans. Sci. Soc. China*, 7, 225-32 (1932); *Chem. Abstr.*, 26, 5555 (1932).

⁵⁷Freon, *Compt. rend.*, 200, 464-6 (1935); *Chem. Abstr.*, 29, 2918 (1935).

⁵⁸Forster, *Proc. Chem. Soc.*, 20, 207 (1904).

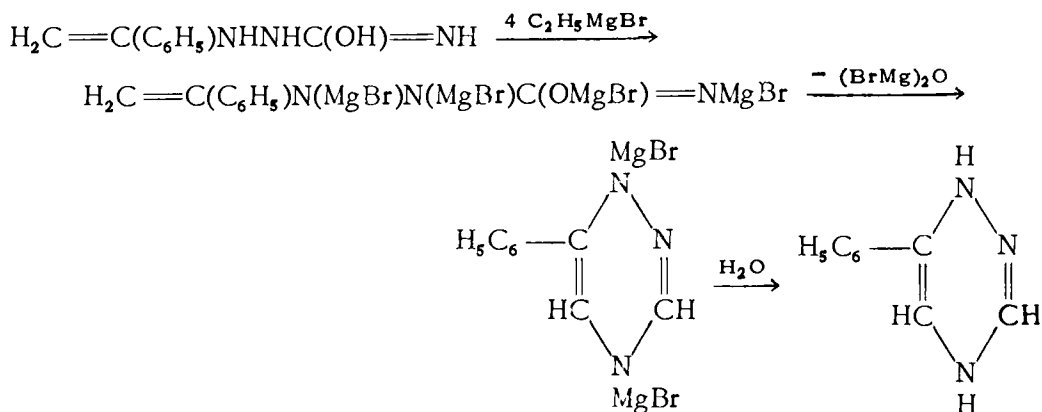
⁵⁹Sen, *J. Indian Chem. Soc.*, 15, 537-42 (1938); *Chem. Abstr.*, 33, 2506 (1939).

⁶⁰Longo, *Gazz. chim. ital.*, 65, 84-8 (1935); *Chem. Abstr.*, 29, 3983 (1935).

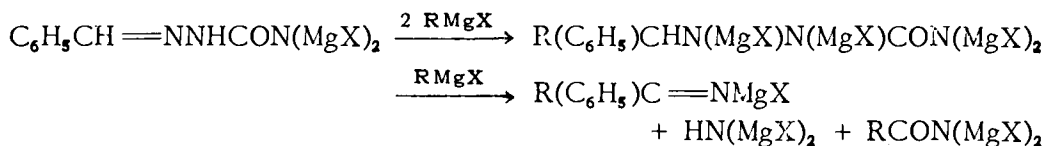


It is of some interest that ethylmagnesium bromide is reported to effect a partial conversion of the *syn* to the *anti* form of 4-BrC₆H₄C(=NOH)CH=CHC₆H₅.⁶¹

Semicarbazones. According to Biquard⁶² the semicarbazone of acetophenone, when treated with an excess (ten molecular equivalents) of ethylmagnesium bromide undergoes replacement of three "active" hydrogen atoms in the cold, and of a fourth upon heating. The product obtained in 60 to 70 percent yield is assigned the structure of 6-phenyl-1,4-dihydro-1,2,4-triazine. It is postulated that the semicarbazone reacts in a form isomeric with that of the conventional formulation, as follows:



Benzaldehyde semicarbazone, which is structurally incapable of the same type of isomerism, reacts with ethylmagnesium bromide to yield (after hydrolysis) propiophenone and propionamide.⁶³ To account for the products isolated, as well as for the absence of urea or its reaction products, the following scheme is suggested:



Biquard found that although both urea and phenylurea react with Grignard reagents, in no case is an amide among the products of the reaction.

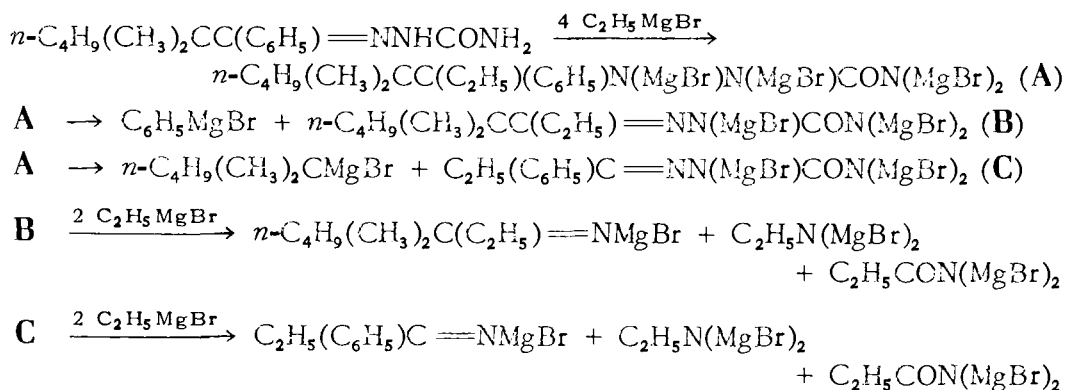
This study was further extended to the semicarbazone of *n*-butyldimethylacetophenone.⁶⁴ From the reaction with ethylmagnesium bromide were obtained 4,4-dimethyl-3-octanone (40 percent), benzene, and a small quantity of propiophenone. The reaction scheme proposed is:

⁶¹ Blatt and Stone, *J. Am. Chem. Soc.*, 53, 4134-49 (1931).

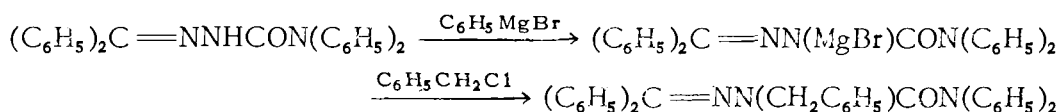
⁶² Biquard, *Bull. soc. chim.*, [5], 3, 656-65 (1936).

⁶³ Biquard, *Bull. soc. chim.*, [5], 3, 666-8 (1936).

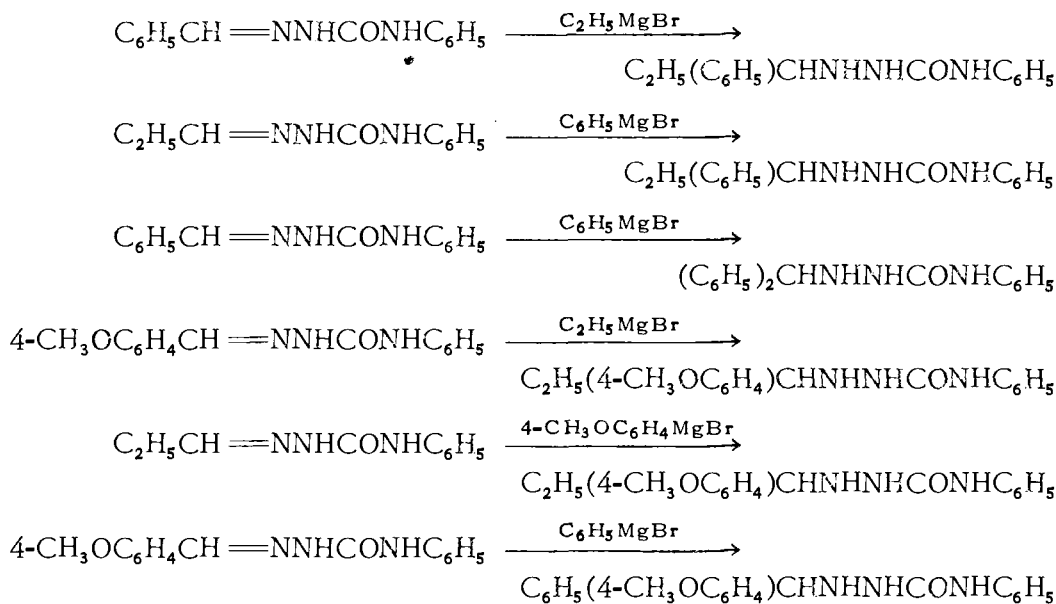
⁶⁴ Biquard, *Bull. soc. chim.*, [5], 5, 207-15 (1938).



According to Gilman *et al.*⁶⁵ benzophenone 4,4-diphenylsemicarbazone reacts with phenylmagnesium bromide, undergoing replacement of one "active" hydrogen atom, and forming an intermediate which can be benzylated with benzyl chloride to yield benzophenone 2-benzyl-4,4-diphenylsemicarbazone.



"Normal" $\text{N}=\text{C}$ double-bond additions of Grignard reagents to the phenylsemicarbazones of aldehydes to give better than 90 percent yields of addition products are reported by Grammaticakis.⁶⁶



DIAZO COMPOUNDS

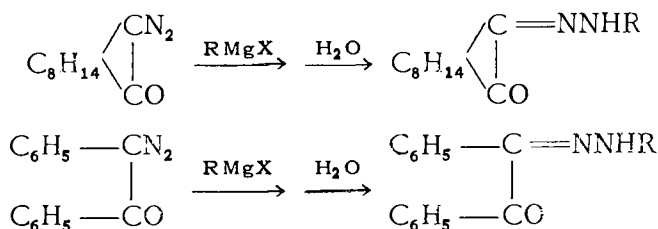
Forster and Cardwell⁶⁷ reported that diazocamphor, when treated with methylmagnesium iodide, yields camphorquinone α -methylhydrazone.

⁶⁵ Coleman, Gilman, Adams, and Pratt, *J. Org. Chem.*, 3, 99-107 (1938).

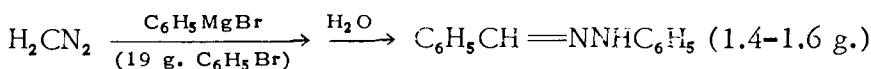
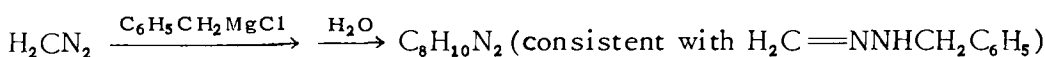
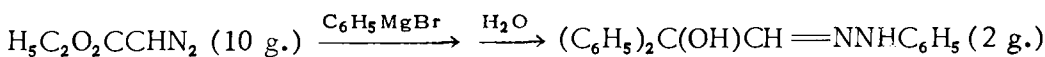
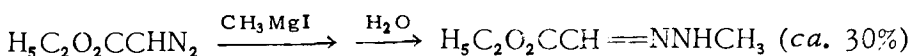
⁶⁶ Grammaticakis, *Compt. rend.*, 228, 323-4 (1949); *Chem. Abstr.*, 43, 3901 (1949).

⁶⁷ Forster and Cardwell, *J. Chem. Soc.*, 103, 861-70 (1913).

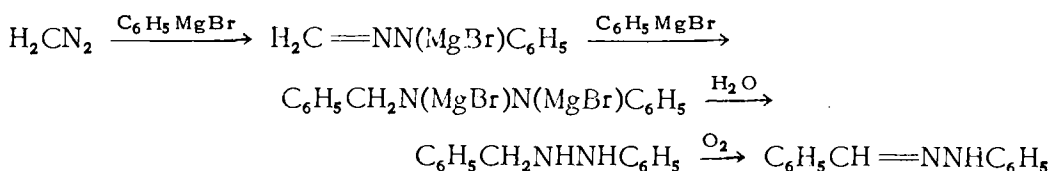
Phenylmagnesium bromide treatment yields the corresponding phenylhydrazone. Diazo deoxybenzoin undergoes comparable reactions to yield the respective benzil hydrazones.



Zerner,⁶⁸ approximately simultaneously, investigated the reactions of several Grignard reagents with diazoacetic ester and diazomethane.

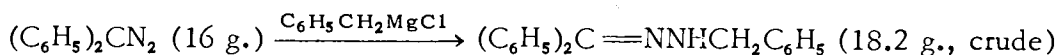
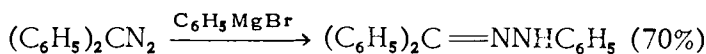
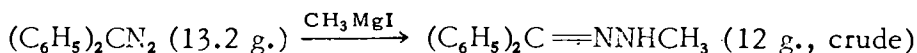


The series of reactions proposed to account for the production of benzaldehyde phenylhydrazone is consistent with the known reactions of diazo compounds and hydrazones (*q.v.*), although, as has been pointed out previously, autoxidation might very well take place prior to, as well as subsequent to, hydrolysis.



Maury⁶⁹ obtained benzaldehyde phenyl- and benzylhydrazones in "good yields" by treatment of phenyldiazomethane with phenylmagnesium bromide and benzylmagnesium chloride, respectively.

Analogous reactions of diphenyldiazomethane are reported by Gilman *et al.*⁷⁰



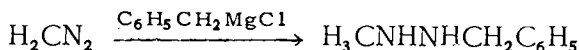
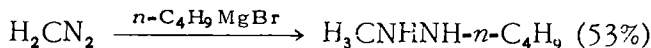
With diazomethane and methylmagnesium iodide or bromide, or with ethylmagnesium iodide, the same investigators obtained only unidentified

⁶⁸ Zerner, *Monatsh.*, 34, 1609-30, 1631-7 (1913); *Chem. Zentr.*, 1914, I, 522, 524.

⁶⁹ Maury, as cited by Coleman, Gilman, Adams, and Pratt, *J. Org. Chem.*, 3, footnote, p. 103 (1938).

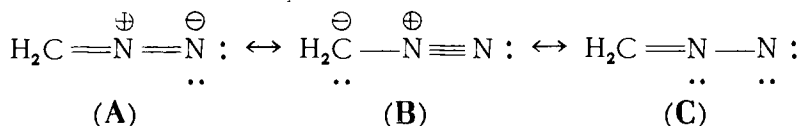
⁷⁰ Coleman, Gilman, Adams, and Pratt, *J. Org. Chem.*, 3, 99-107 (1938).

gaseous products. From the reaction of phenylmagnesium bromide with diazomethane they were able to isolate a 48 percent yield of the 1-phenyl-2-benzylhydrazine which was presumably the predecessor of Zerner's phenylhydrazone. *n*-Butylmagnesium bromide and benzylmagnesium chloride both gave reduction as well as condensation.

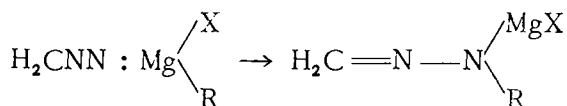


The nature of the reduction reactions is undetermined, but in the case of benzylmagnesium chloride at least it must obviously be of a type different from that of the Grignard reagent reduction of ketones (*q.v.*).

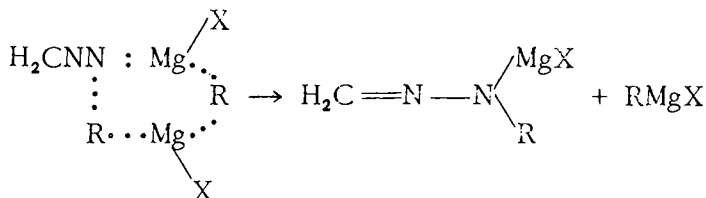
The choice between the classical cyclic formulation for diazomethane and any alternative can scarcely be made on purely chemical grounds. The results of electron-diffraction studies, however, are strongly indicative of a linear configuration, and Boersch⁷¹ has suggested a resonance hybrid of canonical forms **A** and **B**, to which might perhaps be added the further form **C**.



Whatever the relative contributions of the respective resonance forms to the hybrid structure, there is on the terminal nitrogen atom at least one electron-pair available for complex formation with the Grignard reagent. The simplest possibility that suggests itself with regard to mechanism is that a complex of this kind rearranges (as is probably the case with the nitrile-Grignard reagent complexes, *q.v.*).



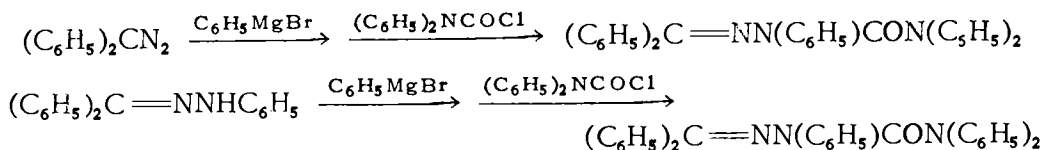
There is also the possibility that the complex originally formed reacts with a second molecule of Grignard reagent (as is probably the case in the ketone additions, *q.v.*).



Other modes of rearrangement or addition are, of course, conceivable.

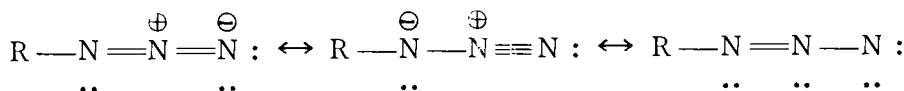
For what the evidence is worth regarding the mode of attachment of groups in an essentially ionic compound, Gilman *et al.* (*loc. cit.*⁷⁰) have carried out the following reaction sequences:

⁷¹Boersch, *Monatsh.*, 65, 311-37 (1935). See also: Ramsay, *J. Chem. Phys.*, 17, 666-7 (1949).

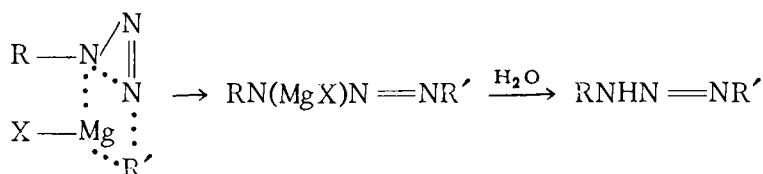


AZIDES

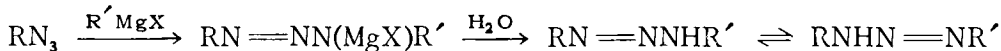
Despite chemical and other arguments to the contrary, the organic azides probably have a linear structure,⁷² which may be regarded as a resonance hybrid:



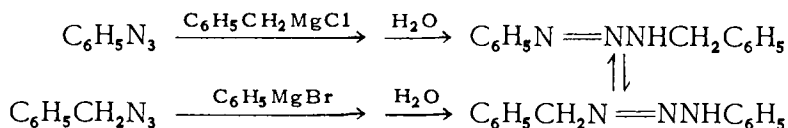
When the cyclic azide formula was in vogue it was the custom to formulate the reaction of an azide with a Grignard reagent as a ring-opening process:



Since it is well-known, however, that the resultant triazenes are tautomeric, there would seem to be no valid *a priori* objection to regarding these reactions as similar in all essential respects to the corresponding reactions of diazo compounds (*q.v.*)



In fact it had been early observed by Dimroth⁷³ that the triazene obtained from the reaction of phenyl azide with benzylmagnesium chloride is identical with that obtained from the reaction of benzyl azide with phenylmagnesium bromide.



In all cases reported in the literature the primary reaction of a Grignard reagent with an azide is apparently the "normal" triazene formation. Data are summarized in Table XIX-III.

Kleinfeller⁷⁴ reports some interesting secondary products apparently resulting from the rearrangement, hydrolysis, and further reaction with azide of the primary products of the reactions of phenyl and *p*-bromophenyl azides with the bifunctional acetylenic Grignard reagent, ($\equiv\text{CMgBr}$)₂.

⁷² See, e.g., Sidgwick, *Trans. Faraday Soc.*, 30, 801-4 (1945).

⁷³ Dimroth, *Ber.*, 38, 670-88 (1905).

⁷⁴ (a) Kleinfeller, *J. prakt. Chem.*, [2], 119, 61-73 (1929); (b) Kleinfeller and Bonig, *ibid.*, [2], 132, 175-99 (1932).

TABLE XIX-III

TRIAZENE (RN_3HR') FORMATION BY REACTION OF AZIDES (RN_3)
WITH GRIGNARD REAGENTS ($R'MgX$)

RN_3	$R'MgX$	Yield (%) RN_3HR'	Ref.
CH_3N_3	CH_3MgI	22*	3
$4-BrC_6H_4N_3$	CH_3MgI	—	4
$4-BrC_6H_4N_3$	$(\equiv CMgBr)_2$	—	5,6
$C_6H_4-1,3-(N_3)_2$	$(\equiv CMgBr)_2$	—	5
$C_6H_4-1,3-(N_3)_2$	C_2H_5MgBr	58	5
$C_6H_4-1,3-(N_3)_2$	C_6H_5MgBr	—	5
$C_6H_5N_3$	CH_3MgI	75	1,2
$C_6H_5N_3$	$(\equiv CMgBr)_2$	—	5,6
$C_6H_5N_3$	C_2H_5MgI	55	2
$C_6H_5N_3$	$H_2C=CHCH_2MgBr$	100 (crude)	7
$C_6H_5N_3$	C_6H_5MgBr	71	1
$C_6H_5N_3$	$C_6H_5CH_2MgCl$	"Good"	2
$C_6H_5N_3$	$4-CH_3C_6H_4MgBr$	—	4
$C_6H_5N_3$	$4-C_2H_5OC_6H_4MgBr$	—	4
$C_6H_5N_3$	$1-C_{10}H_7MgBr$	—	4
$C_6H_5CH_2N_3$	CH_3MgI	88†	2
$C_6H_5CH_2N_3$	C_6H_5MgBr	"Good"	2
$4-CH_3C_6H_4N_3$	CH_3MgI	—	4
$4-C_2H_5OC_6H_4N_3$	CH_3MgI	—	4
$4-C_2H_5OC_6H_4N_3$	C_6H_5MgBr	—	4
$1-C_{10}H_7N_3$	C_6H_5MgBr	—	4

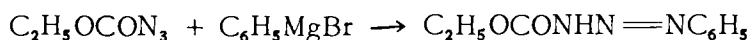
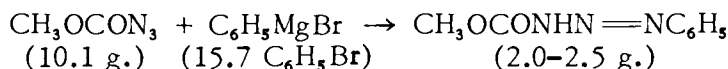
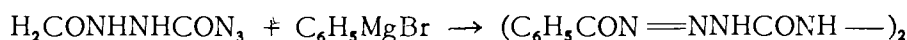
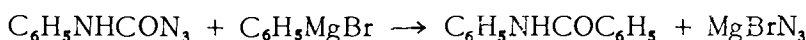
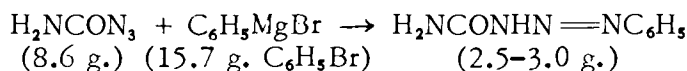
* Isolated as cuprous salt, $Cu^+(CH_3N_3CH_3)^-$, for which stated yield is reported.

† Isolated as silver salt, $Ag^+(C_6H_5N_3CH_3)^-$, for which stated yield is reported.

REFERENCES FOR TABLE XIX-III

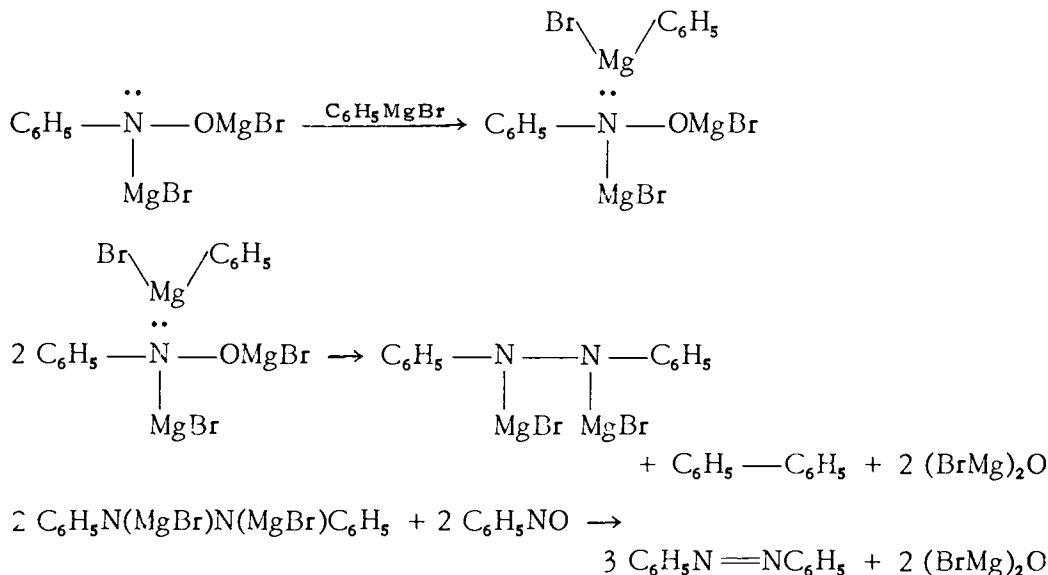
- (1) Dimroth, *Ber.*, 36, 909-13 (1903).
- (2) Dimroth, *Ber.*, 38, 670-88 (1905).
- (3) Dimroth, *Ber.*, 39, 3905-12 (1905).
- (4) Dimroth, Eble, and Gruhl, *Ber.*, 40, 2390-401 (1907).
- (5) Kleinfeller, *J. prakt. Chem.*, [2], 119, 61-73 (1929).
- (6) Kleinfeller and Bönig, *J. prakt. Chem.*, [2], 132, 175-99 (1932).
- (7) Pochinok, *J. Gen. Chem. (U.S.S.R.)*, 16, 1303-5 (1946); *Chem. Abstr.*, 41, 3066 (1947).

Berthot^{74,1} reports reactions of phenylmagnesium bromide with various acyl and carbalkoxy azides as follows:



^{74,1} Berthot, *J. prakt. Chem.*, [2], 116, 101-17 (1927).

⁷⁸ Bachmann, *J. Am. Chem. Soc.*, **53**, 1524-31 (1931).



On the basis of the scanty evidence available it would appear that low-temperature ($< -10^\circ$) operation favors the hydrazo reduction over the "normal" addition. Data are summarized in Table XIX-IV. When reported, percentage yields are stated; otherwise a plus sign in the appropriate column indicates the product isolated. No significance need be attached to the fact that a product is not reported as present in any given instance.

No reactions of simple *t*-alkyl nitroso compounds have been reported. Tilden *et al.*⁷⁹ have reported reactions of methylmagnesium iodide with pinene and α - and β -limonene nitrosochlorides, but in view of the probable uncertainties regarding the structures of both starting materials and products, no theoretical conclusions can be drawn from their work.

Aston and Menard⁸⁰ report a variety of dehydrohalogenation, reduction, and condensation reactions of 2-bromo- and 2-chloro-2-nitrosopropane, but no generalizations can be based on this study.

N-NITROSOAMINES

From the meagre data available it would appear that the "normal" primary reaction of a nitrosoamine with a Grignard reagent consists in addition at the nitrogen-oxygen double bond.

According to Wieland and Fressel,⁸¹ ethylmagnesium iodide reacts with *N*-nitrosodiethylamine to form the diethylhydrazone of acetaldehyde. The reaction with *N*-nitrosodiphenylamine is similar. These reactions are accompanied by the evolution of a gas "recognized as ethane."

⁷⁹(a) Tilden and Stokes, *J. Chem. Soc.*, 87, 836-40 (1905); (b) Tilden and Shephard, *ibid.*, 89, 920-3 (1906).

⁸⁰Aston and Menard, *J. Am. Chem. Soc.*, 57, 1920-4 (1935).

⁸¹Wieland and Fressel, *Ber.*, 44, 898-904 (1911).

TABLE XIX-IV
REACTIONS OF NITROSO COMPOUNDS WITH GRIGNARD REAGENTS

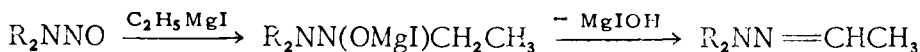
<u>RNO</u>	<u>R'MgX</u>	<u>RR'NOH</u>	<u>RR'NH</u>	<u>(RN=)</u> ₂	<u>(RNH—)</u> ₂	<u>Ref.</u>
C ₆ H ₅ NO	AlkMgX	...	...	(?)*	...	1
C ₆ H ₅ NO	C ₆ H ₅ MgBr	ca. 50%	+	+	...	2,3,5
C ₆ H ₅ NO	C ₆ H ₅ MgBr	...	33.1%	+	...	7
C ₆ H ₅ NO	Mg + MgI ₂	...	...	...	+	8
C ₆ H ₅ NO	Mg + 2 MgI ₂	...	...	71%	...	9
C ₆ H ₅ NO	Mg + 4 MgI ₂	...	...	...	66%	9
4-CH ₃ C ₆ H ₄ NO	C ₆ H ₅ MgBr	ca. 40%	...	...	...	6
4-CH ₃ C ₆ H ₄ NO	4-CH ₃ C ₆ H ₄ MgBr	40-50%	...	...	...	4,5
4-CH ₃ OC ₆ H ₄ NO	C ₆ H ₅ MgBr	...	...	+	...	6
4-(CH ₃) ₂ NC ₆ H ₄ NO	C ₂ H ₅ MgBr	...	...	+	...	6
4-(CH ₃) ₂ NC ₆ H ₄ NO	C ₆ H ₅ MgBr	...	...	+	...	6
4-(CH ₃) ₂ NC ₆ H ₄ NO	C ₆ H ₅ MgBr	...	26.4%	...	...	7
4-(CH ₃) ₂ NC ₆ H ₄ NO	4-CH ₃ OC ₆ H ₄ MgBr	...	...	+	...	6

* Actually, the product is reported as "a crystalline yellow base."

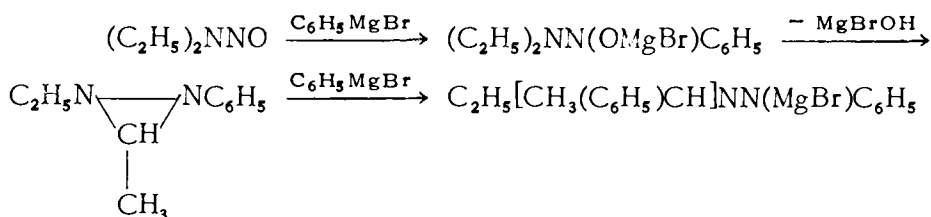
REFERENCES FOR TABLE XIX-IV

- (1) Wieland, *Ber.*, 36, 2315-9 (1903).
- (2) Wieland and Roseeu, *Ber.*, 45, 494-9 (1912).
- (3) Wieland and Offenbächer, *Ber.*, 47, 2111-5 (1914).
- (4) Wieland and Roseeu, *Ber.*, 48, 1117-21 (1915).
- (5) Wieland and Roth, *Ber.*, 53B, 210-30 (1920).
- (6) Wieland and Kögl, *Ber.*, 55B, 1798-803 (1922).
- (7) Gilman and McCracken, *J. Am. Chem. Soc.*, 49, 1052-61 (1927).
- (8) Gilman and Heck, *Rec. trav. chim.*, 50, 522-4 (1931).
- (9) Bachmann, *J. Am. Chem. Soc.*, 53, 1524-31 (1931).

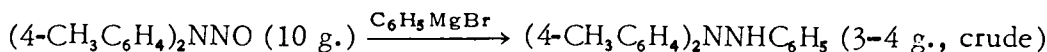
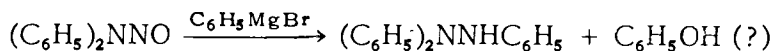
This has the appearance of a "normal" addition, followed by the equivalent of a dehydration.*



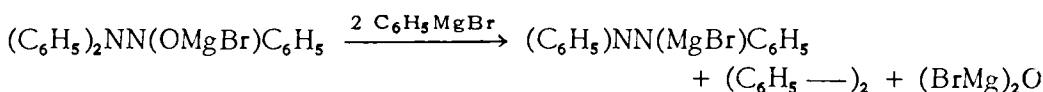
When phenylmagnesium bromide reacts with *N*-nitrosodiethylamine the reported⁸¹ products are phenyldiethylhydrazine (an addition-reduction product) and 1-ethyl-1- α -phenylethyl-2-phenylhydrazine (possibly an addition-"dehydration"-addition product). A reaction scheme which might conceivably account for the formation of the latter product is as follows:



The reported⁸² products of the reactions of *N*-nitrosodiarylamines with arylmagnesium halides are the triarylhydrazines.



The nature of the reduction has not been established. Although Wieland^{82b} has detected phenol in one such reaction mixture, this in itself is irrelevant. The present authors have found that when no special precautions are taken to exclude oxygen it is often possible to isolate 8-10 percent of phenol from phenylmagnesium bromide reaction mixtures. By analogy with the corresponding hydroxylamine reductions (*q.v.*), the co-product of this reduction should be biphenyl.



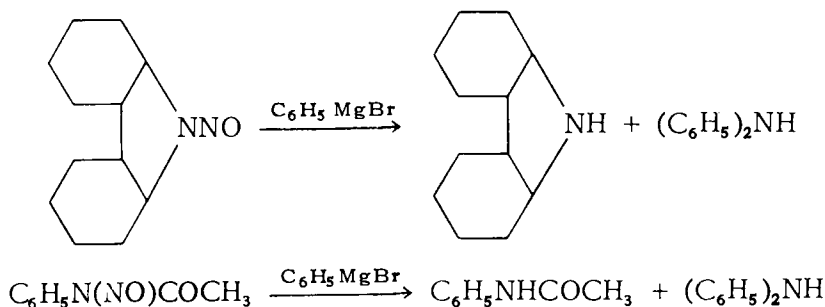
Gilman and Heck⁸³ state, without detailed specification of experimental conditions, that attempted reduction of *N*-nitrosodiphenylamine with magnesium-magnesium iodide led chiefly to recovery of unchanged material (together with a little tar formation). They also remark in passing that preliminary experiments with the *N*-nitrosodiphenylamine-phenylmagnesium bromide reaction have led to the isolation of a product which is "apparently *o*-anilinothriphenylamine or an isomer."

* It is, of course, conceivable that the sequence is addition, reduction, and autoxidation, but the corresponding phenylmagnesium bromide reaction makes the hypothesis stated seem more attractive on the ground that autoxidation prior to hydrolysis would probably be insufficient. No critical conclusions can be drawn until such experiments are performed quantitatively with careful oxygen exclusion, and all the products are isolated and positively identified.

⁸²(a) Wieland and Reverdy, *Ber.*, 48, 1112-6 (1915); (b) Wieland and Roseau, *ibid.*, 48, 1117-21 (1915).

⁸³Gilman and Heck, *Rec. trav. chim.*, 50, 522-4 (1931).

Other reported reactions (Wieland, *loc. cit.*^{82b}) unsupported by data sufficient to warrant discussion are:

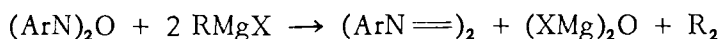


Insofar as the Grignard reactions of nitrosoamines are of any theoretical interest whatsoever, they invite the expenditure of about one first-class doctoral dissertation.

AZOXY COMPOUNDS, FUROXANS, AMINE OXIDES, AND NITRILE OXIDES

Gilman and Heck⁸³ report an "excellent yield" of azobenzene upon reduction of azoxybenzene with magnesium-magnesium iodide. Using one equivalent of this reducing agent with azoxybenzene Bachmann⁸⁴ obtained a 94 percent yield of azobenzene; with two equivalents he obtained hydrazobenzene in 92 percent yield. Bachmann also found that the reduction product of azobenzene reduces an equivalent of azoxybenzene, being simultaneously oxidized to azobenzene; the overall yield of azobenzene was *ca.* 93 percent.

According to Kursanov *et al.*⁸⁵ azoxybenzene and *p,p'*-azoxytoluene are both reduced by Grignard reagents to the corresponding azo compounds. The reduction is evidently of the same type as that of the hydroxylamines (*q.v.*).



Kursanov's data are summarized in Table XIX-V.

TABLE XIX-V
REDUCTION OF AZOXY COMPOUNDS BY GRIGNARD REAGENTS

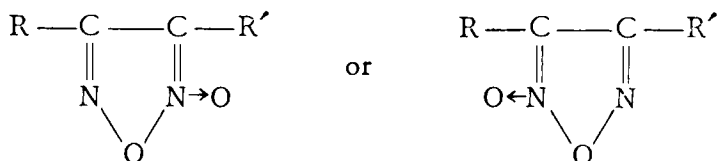
$(\text{ArN})_2\text{O}$	RMgX	$(\text{ArN}=\text{N})_2$ (%)	R_2 (%)
$(\text{C}_6\text{H}_5\text{N})_2\text{O}$	$\text{C}_6\text{H}_5\text{MgBr}$	95.8	64.4
$(\text{C}_6\text{H}_5\text{N})_2\text{O}$	$4\text{-CH}_3\text{C}_6\text{H}_4\text{MgCl}$	+	+
$(\text{C}_6\text{H}_5\text{N})_2\text{O}$	$1\text{-C}_{10}\text{H}_7\text{MgBr}$	+	56.3
$(\text{C}_6\text{H}_5\text{N})_2\text{O}$	$(\text{C}_6\text{H}_5)_2\text{CHMgBr}$	66.3	71.7
$(4\text{-CH}_3\text{C}_6\text{H}_4\text{N})_2\text{O}$	$\text{C}_6\text{H}_5\text{MgBr}$	60.1	83.5
$(4\text{-CH}_3\text{C}_6\text{H}_4\text{N})_2\text{O}$	$\text{C}_6\text{H}_5\text{CH}_2\text{MgCl}$	73.8	36.3

The question of the proper formulation of the so-called "glyoxime peroxides," or furoxans, has been the subject of some disagreement.

⁸⁴ Bachmann, *J. Am. Chem. Soc.*, 53, 1524-31 (1931).

⁸⁵ Kursanov, Kursanova, and Blokhina, *J. Gen. Chem. (U.S.S.R.)*, 8, 1786-90 (1938); *Chem. Abstr.*, 33, 4979 (1939).

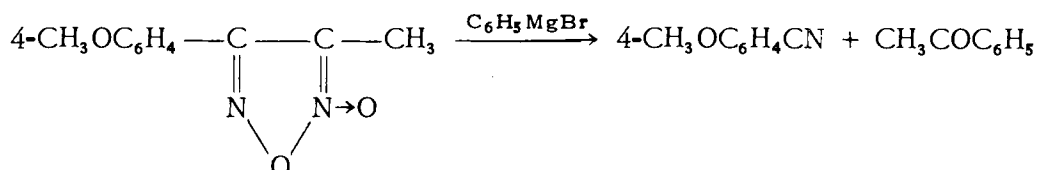
According to present-day valence concepts the preferable formulation is probably that of a 1,2,5-isoxadiazole oxide.⁸⁶ In the case of the unsymmetrically substituted derivatives, however,



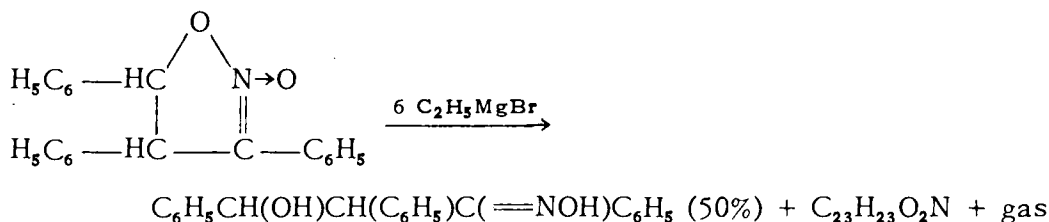
this poses a more or less arbitrary choice as to the point of attachment of the oxide oxygen. Probably no static formula does justice to the facts.

Wieland and Semper⁸⁷ report that "methylanisylglyoxime peroxide" forms with ethereal methylmagnesium iodide a yellow, insoluble complex, which, upon hydrolysis, regenerates the original compound.

According to Bigiavi,⁸⁸ Angeli (no reference cited) effected the cleavage of "methyl-3,4-methylenedioxyphenylglyoxime peroxide" with phenylmagnesium bromide and obtained as products piperonylonitrile and acetophenone. Bigiavi (*loc. cit.*⁸⁸) refluxed the same furoxan with methylmagnesium iodide in benzene for six hours and recovered piperonylonitrile and 3,4-methylenedioxyacetophenone. Similar treatment of the methylanisyl derivative with phenylmagnesium bromide yielded anisonitrile and an unstable product, designated as 1-nitroso-1-phenylethanol, which decomposes to yield acetophenone.



Kohler and Barrett⁸⁹ treated 3,4,5-triphenylisoxazoline oxide with six equivalents of ethylmagnesium bromide and obtained, in 50 percent yield, a reduction product which they formulated as the *N*-hydroxyisoxazolidine. This characterization was subsequently abandoned in favor of an open-chain oxime formulation.⁹⁰



⁸⁶ See, e.g., Smith, *Chem. Revs.*, 23, 193-285 (1938).

⁸⁷ Wieland and Semper, *Ann.*, 358, 36-70 (1908).

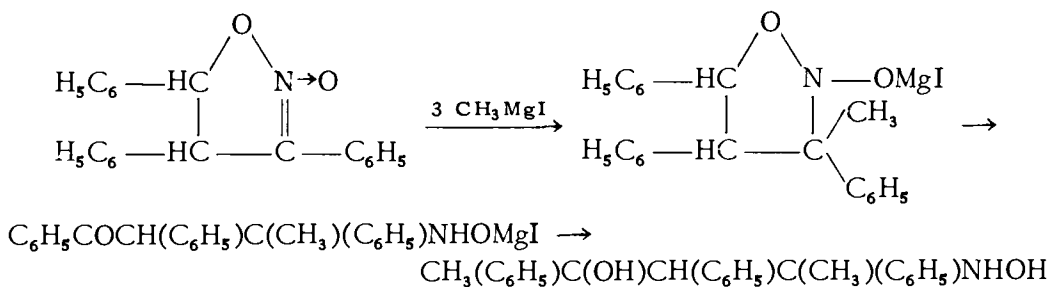
⁸⁸ Bigiavi, *Gazz. chim. ital.*, 51, 11, 324-9 (1922); *Chem. Abstr.*, 16, 1394 (1922).

⁸⁹ Kohler and Barrett, *J. Am. Chem. Soc.*, 46, 2105-13 (1924).

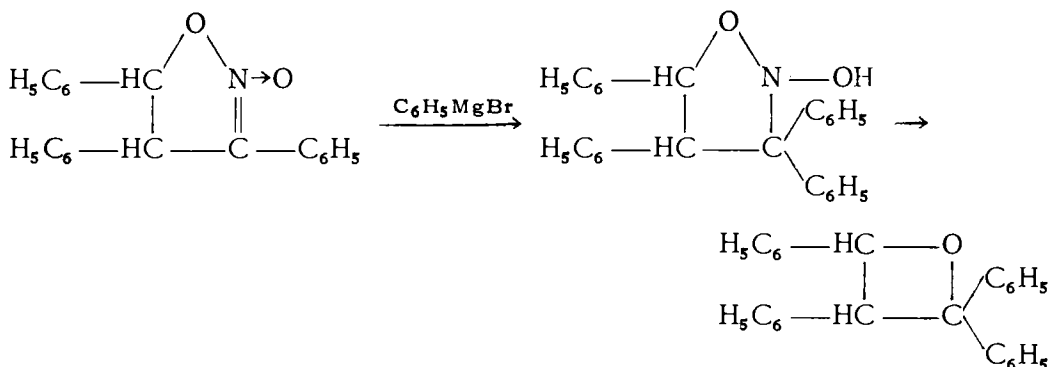
⁹⁰ Kohler and Richtmyer, *J. Am. Chem. Soc.*, 52, 2038-46 (1930).

Upon treatment of the same isoxazoline oxide (0.06 mole) with excess benzylmagnesium chloride Kohler and Richtmyer (*loc. cit.*⁹⁰) obtained the same oxime in *ca.* 65 percent yield (0.039 mole), together with bibenzyl (0.053 mole, corresponding to 0.107 mole Grignard reagent).*

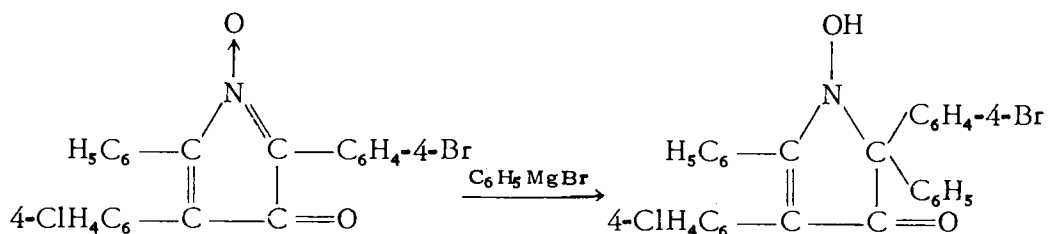
Methylmagnesium iodide formed an addition product which Kohler and Richtmyer (*loc. cit.*⁹⁰) account for as follows:



Phenylmagnesium bromide gave a nitrogen-free product which Kohler and Richtmyer (*loc. cit.*⁹⁰) formulate as an oxetane.



With 2,4,5-triphenyl-3-pyrroleninone oxide and phenylmagnesium bromide Kohler and Addinall⁹¹ obtained a 1,3-addition product in 85 percent yield. The corresponding 2-*p*-bromophenyl-4-*p*-chlorophenyl-5-phenyl compound reacted similarly.

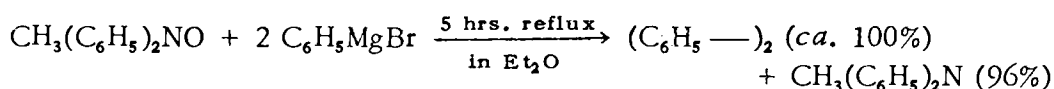
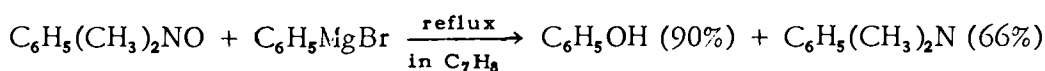


Belov and Savich⁹² make the astonishing report that dimethylaniline oxide reacts with phenylmagnesium bromide to yield dimethylaniline and phenol, whereas methyldiphenylamine oxide yields methyldiphenylamine and biphenyl:

* Part of the bibenzyl was undoubtedly formed during the preparation of the Grignard reagent.

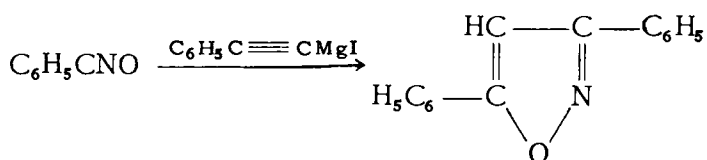
⁹¹ Kohler and Addinall, *J. Am. Chem. Soc.*, 52, 1590-604 (1930).

⁹² Belov and Savich, *J. Gen. Chem. (U.S.S.R.)*, 17, 262-8 (1947); *Chem. Abstr.*, 42, 530 (1948).



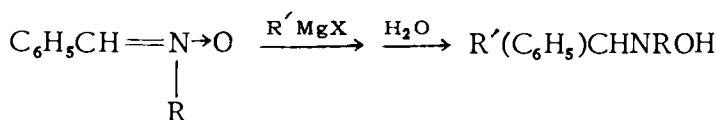
These experiments should be repeated with Grignard reagents prepared from sublimed magnesium.

From the reaction of benzonitrile oxide with methylmagnesium iodide Wieland⁹³ obtained acetophenone oxime, acetophenone, and a little benzonitrile. By a similar reaction with phenylethynylmagnesium iodide Palazzo⁹⁴ succeeded in preparing 3,5-diphenylisoxazole.



Ponzio⁹⁵ reports that a compound to which he assigns the constitution of the oxide of benzoyl cyanide oxime is converted by methylmagnesium iodide to methylphenylglyoxime.

According to Angeli *et al.*⁹⁶ "N-phenylbenzaldoxime" reacts additively with ethylmagnesium iodide and phenylmagnesium bromide. The N-benzyl derivative reacts similarly with phenylmagnesium bromide.



HYDROXYLAMINES AND ALKOXYAMINES

The possibility of preparing primary amines by the reaction of Grignard reagents with hydroxylamine was investigated by Weissberger *et al.*⁹⁷ In a typical experiment, performed under nitrogen, a phenylmagnesium bromide-hydroxylamine reaction mixture was allowed to stand at 0° for one hour, and then for another hour at room temperature. The yield of aniline was 2.4 percent, based on the bromobenzene employed, or 8.5 percent, based on the hydroxylamine used. Other products isolated were: benzene (66.9 percent); biphenyl (15.3 percent); phenol (2.2 percent); and ammonia (22.3 percent).

Paolini and Paolini⁹⁸ have found that by the Zerewitinoff method (*q.v.*), hydroxylamine, N-benzoylhydroxylamine, and N-phenylsulfonylhydroxyl-

⁹³ Wieland, *Ber.*, 40, 1667-76 (1907).

⁹⁴ Palazzo, *Gazz. chim. ital.*, 77, 214-21 (1947); *Chem. Abstr.*, 42, 904 (1948).

⁹⁵ Ponzio, *Gazz. chim. ital.*, 53, 507-13 (1923); *Chem. Abstr.*, 17, 3876 (1923).

⁹⁶ Angeli, Alessandri, and Aiazzi-Mancini, *Atti accad. Lincei*, 20, I, 546-55 (1911); *Chem. Abstr.*, 5, 3403 (1911).

⁹⁷ Weissberger, Fasold, Bach, *J. prakt. Chem.*, [2], 124, 29-32 (1929).

⁹⁸ Paolini and Paolini, *Gazz. chim. ital.*, 62, 1059-65 (1932); *Chem. Abstr.*, 27, 2672 (1933).

amine all reveal the presence of two "active" hydrogen atoms per molecule. Benzoylation of the halomagnesium hydroxylamine derivative (with benzoyl chloride) yields *N*-benzoxybenzamide ($C_6H_5CONHO_2CC_6H_5$).

Heated at 100° for several hours with ethylmagnesium bromide, *N*-phenylsulfonylhydroxylamine is reduced to benzenesulfonamide. *N*-*p*-Tolylsulfonylhydroxylamine undergoes similar reduction.

Busch and Hobein⁹⁹ reported a 20 percent yield of triphenylhydrazine from the reaction of phenylhydrazine with phenylmagnesium bromide. With *p*-chlorophenylhydrazine they obtained *p,p'*-dichloroazobenzene.

With magnesium-magnesium iodide reducing mixture Gilman and Heck¹⁰⁰ obtained azobenzene and aniline from phenylhydroxylamine.

Wieland and Roseeu¹⁰¹ had correctly assumed that a diphenylhydroxylamine derivative is the primary product of the reaction of nitrosobenzene with phenylmagnesium bromide, but mistakenly postulated that the further reduction to diphenylamine takes place through the reaction:

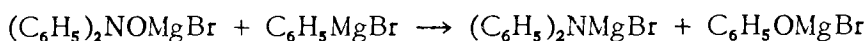


TABLE XIX-VI

REACTIONS OF ALKOXYAMINES WITH GRIGNARD REAGENTS

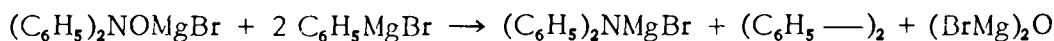
$RONH_2$	$R'MgX$	$R'NH_2$ (%)	Authors
CH_3ONH_2	C_2H_5MgBr	67	S. & K. ^{103a}
CH_3ONH_2	$n-C_4H_9MgCl$	58	B. & J. ¹⁰⁴
CH_3ONH_2	$n-C_4H_9MgBr$	63	B. & J. ¹⁰⁴
CH_3ONH_2	$i-C_4H_9MgBr$	90	B. & J. ¹⁰⁴
CH_3ONH_2	$s-C_4H_9MgCl$	73	S. & K. ^{103a}
CH_3ONH_2	$t-C_4H_9MgCl$	74	S. & K. ^{103a}
CH_3ONH_2	$t-C_4H_9MgCl$	70	B. & J. ¹⁰⁴
CH_3ONH_2	$BrMg(CH_2)_5MgBr$	68	B. & J. ¹⁰⁴
CH_3ONH_2	$i-C_5H_{11}MgCl$	80	S. & K. ^{103a}
CH_3ONH_2	$i-C_5H_{11}MgBr$	71	S. & K. ^{103a, b}
CH_3ONH_2	$i-C_5H_{11}MgI$	5	S. & K. ^{103a}
CH_3ONH_2	$4-BrC_6H_4MgBr$	73	S. & K. ^{103a}
CH_3ONH_2	C_6H_5MgBr	65	S. & K. ^{103a, b}
CH_3ONH_2	C_6H_5MgI	<1	S. & K. ^{103a}
CH_3ONH_2	$BrMg(CH_2)_6MgBr$	51	B. & J. ¹⁰⁴
CH_3ONH_2	$BrMg(CH_2)_{10}MgBr$	53	B. & J. ¹⁰⁴
$C_6H_5CH_2ONH_2$	C_2H_5MgBr	46	S. & K. ^{103b}
$C_6H_5CH_2ONH_2$	$i-C_5H_{11}MgBr$	67	S. & K. ^{103b}
$C_6H_5CH_2ONH_2$	$4-BrC_6H_4MgBr$	58	S. & K. ^{103b}
$C_6H_5CH_2ONH_2$	C_5H_5MgBr	57	S. & K. ^{103b}
$C_6H_5CH_2ONH_2$	C_6H_5MgI	7	S. & K. ^{103b}
$C_6H_5CH_2ONH_2$	$(CH_2)_5CHMgBr$	62	S. & K. ^{103b}
$C_6H_5CH_2ONH_2$	$C_6H_5CH_2MgCl$	79	S. & K. ^{103b}
$C_6H_5CH_2ONH_2$	$2,4,6-(CH_3)_3C_6H_2MgBr$	25	S. & K. ^{103b}
$C_6H_5CH_2ONH_2$	$1-C_{10}H_7MgBr$	38	S. & K. ^{103b}

⁹⁹ Busch and Hobein, *Ber.*, 40, 2099-102 (1907).

¹⁰⁰ Gilman and Heck, *Rec. trav. chim.*, 50, 522-4 (1931).

¹⁰¹ Wieland and Roseeu, *Ber.*, 48, 1117-21 (1915).

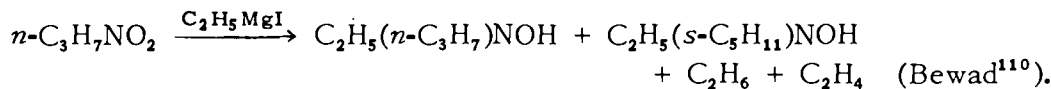
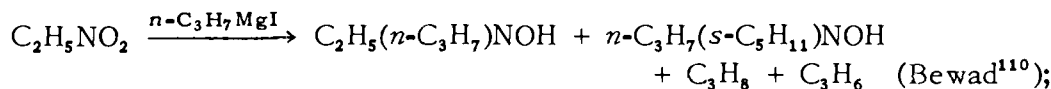
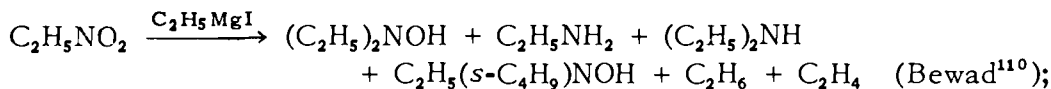
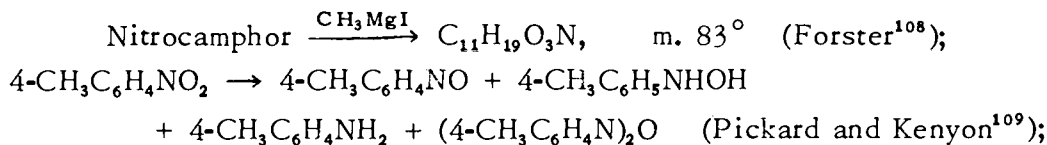
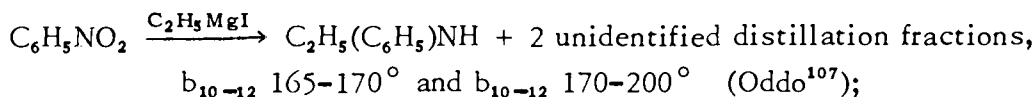
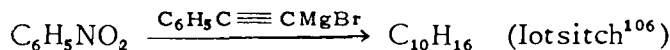
It was shown by Gilman and McCracken¹⁰² that this reduction requires two equivalents, rather than one, of the Grignard reagent, and that the co-product is biphenyl rather than phenol.



Primary amines may be prepared in rather satisfactory yields by the reactions of alkoxyamines with organomagnesium chlorides or bromides (but not iodides) at -10 to -15° . Preparations reported by Sheverdina and Kocheshkov¹⁰³ and by Brown and Jones¹⁰⁴ are summarized in Table XIX-VI.

NITRO COMPOUNDS

The reaction of a nitro compound with a Grignard reagent was first investigated by Moureu,¹⁰⁵ who announced the preparation, in unspecified yield, of *N,N*-diethylhydroxylamine from nitroethane and ethylmagnesium iodide. Other early reports of such reactions are as follows:



¹⁰² Gilman and McCracken, *J. Am. Chem. Soc.*, 49, 1052-61 (1927).

¹⁰³ Sheverdina and Kocheshkov, (a) *J. Gen. Chem.* (U.S.S.R.), 8, 1825-30 (1938); *Chem. Abstr.*, 33, 5804 (1939); (b) *Bull. acad. sci. U.R.S.S., Classe sci. chim.*, 1941, 75-8; *Chem. Zentr.*, 1942, I, 1872; *Chem. Abstr.*, 37, 3066 (1943).

¹⁰⁴ Brown and Jones, *J. Chem. Soc.*, 1946, 781-2.

¹⁰⁵ Moureu, *Compt. rend.*, 132, 837-9 (1901); *Chem. Zentr.*, 1901, I, 1000.

¹⁰⁶ Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 35, 555 (1903); *Bull. soc. chim.*, [3], 32, 719 (1904).

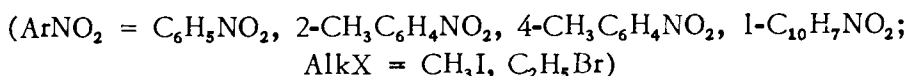
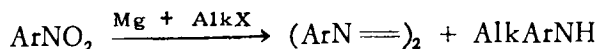
¹⁰⁷ Oddo, *Atti accad. Lincei*, [5], 13, II, 220-4 (1904); *Chem. Zentr.*, 1904, II, 1113.

¹⁰⁸ Forster, *Proc. Chem. Soc.*, 20, 207 (1904).

¹⁰⁹ Pickard and Kenyon, *Proc. Chem. Soc.*, 23, 153 (1907).

¹¹⁰ Bewad, *Ber.*, 40, 3065-83 (1907).

The earlier literature has been reviewed and discussed by Hepworth¹¹¹ who also carried out some Barbier-type reactions with aryl nitro compounds and alkyl halides.



From the reaction mixture of 123 g. of nitrobenzene, 42 g. of magnesium, and 175 g. of ethyl bromide, he isolated 27 g. (ca. 30 percent) of azobenzene and 25 g. (ca. 21 percent) of *N*-ethylaniline.

Gilman and Heck¹¹² found the reaction of magnesium-magnesium iodide with nitrobenzene "slow and limited in extent." Under the not very precisely defined conditions employed they effected a 65 percent recovery of nitrobenzene, and were able to isolate only a little aniline as a reduction product.

Wang¹¹³ has undertaken a summarization of the facts concerning the interactions of nitro compounds and Grignard reagents as follows: (1) aliphatic nitro compounds give β,β -disubstituted hydroxylamines; (2) aromatic nitro compounds and alkylmagnesium halides give *s*-tetrasubstituted hydrazines; and (3) aromatic nitro compounds and arylmagnesium halides give secondary amines. As will be seen from the data cited, this presents rather too simple a picture.

According to Buckley,¹¹⁴ when ethyl nitrate is combined with one equivalent of ethylmagnesium bromide solution at 0° a vigorous exothermic reaction takes place, and a solid complex $[(\text{C}_2\text{H}_5)_2\text{N}(\rightarrow\text{O})\text{OMgBr}]$ separates from the solution. No gas is evolved in this phase of the reaction. When an additional two equivalents of Grignard reagent is added, the complex for the most part dissolves, and one equivalent of gas is evolved. The chief liquid product is *N,N*-diethylhydroxylamine; one equivalent of Grignard reagent remains unchanged.

When the intermediate $(\text{C}_2\text{H}_5)_2\text{N}(\rightarrow\text{O})\text{OMgBr}$ is reduced with zinc and hydrochloric acid, a 60 percent yield of diethylamine is obtained. The analogous intermediate from methyl nitrate and ethylmagnesium bromide yields 63 percent methylethylamine. Similar intermediates are obtained from isopropyl and *t*-butyl nitrates, but attempts to reduce them with zinc and hydrochloric acid fail because of their instability.

Kursanov and Solodkov¹¹⁵ have investigated some reactions of aromatic nitro compounds with arylmagnesium halides, and have characterized the

¹¹¹ Hepworth, *J. Chem. Soc.*, 117, 1004-12 (1920). See also: Oddo, *Gazz. chim. ital.*, 41,1, 273-94 (1911); *Chem. Abstr.*, 5, 2639 (1911).

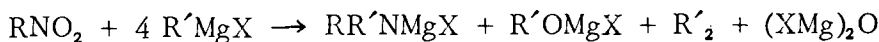
¹¹² Gilman and Heck, *Rec. trav. chim.*, 50, 522-4 (1931).

¹¹³ Wang, *Trans. Sci. Soc. China*, 7, 253-63 (1932); *Chem. Abstr.*, 26, 5545 (1932).

¹¹⁴ Buckley, *J. Chem. Soc.*, 1947, 1492-4.

¹¹⁵ Kursanov and Solodkov, *J. Gen. Chem. (U.S.S.R.)*, 5, 1487-93 (1935); *Chem. Abstr.*, 30, 2181 (1936).

overall reaction as follows:



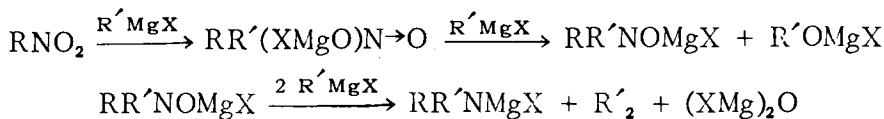
Their data are summarized in Table XIX-VII. The formation of biaryls is strongly suggestive of a radical process.

TABLE XIX-VII

REACTIONS OF ARYL NITRO COMPOUNDS WITH ARYLMAGNESIUM HALIDES

<u>RNO₂</u>	<u>R'MgX</u>	<u>RR'NH (%)</u>	<u>R'OH (%)</u>	<u>R'₂ (%)</u>
C ₆ H ₅ NO ₂	C ₆ H ₅ MgBr	62	63	50
C ₆ H ₅ NO ₂	4-CH ₃ C ₆ H ₄ MgBr	60	55	69
C ₆ H ₅ NO ₂	1-C ₁₀ H ₇ MgBr	—	44	—
1-C ₁₀ H ₇ NO ₂	C ₆ H ₅ MgBr	49	64	62

Assuming, as Kursanov and Solodkov (*loc. cit.*¹¹⁵) do, that the initial reaction of an aryl nitro compound with an arylmagnesium halide consists in an addition followed by a reduction to a diarylhydroxylamine derivative, the further reduction to a diarylamine derivative is readily accounted for by the study of Gilman and McCracken.¹¹⁶



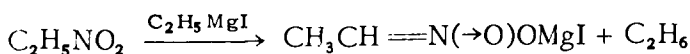
However, it is conceivable that the initial reduction may precede addition, and that nitrosobenzene is the primary intermediate, or at least one of the possible intermediates, of the reaction. That reduction may take place without addition is indicated by the "preliminary study" of Pickard and Kenyon (*loc. cit.*¹⁰⁹), although in this case it is not stated whether the Grignard reagent was alkyl or aryl.

Apparently a similar gross reaction sequence (though not necessarily with the same reaction mechanisms) may take place, at least in part, with aryl nitro compounds and alkylmagnesium halides, as witness the products of Hepworth's (*loc. cit.*¹¹¹) reactions.

The formation of an azo compound might be attributed to interaction between nitroso compound and the corresponding amine (or between their respective halomagnesium derivatives). An alternative scheme has been suggested in the discussion of the reactions of nitroso compounds (*q.v.*). An azoxy compound might result similarly from interaction between a nitroso compound and the corresponding hydroxylamine (or their respective halomagnesium derivatives).

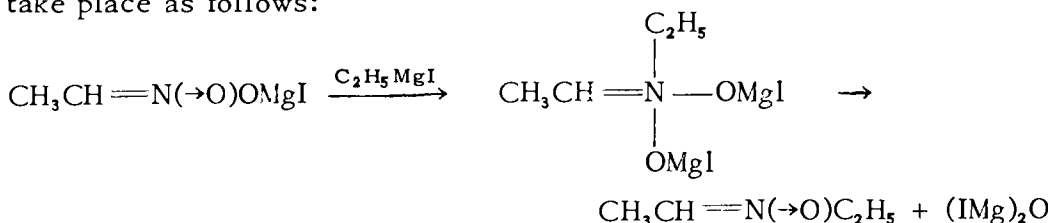
Bewad's study (*loc. cit.*¹¹⁰) suggests that an isoöxime (nitrone) may be one of the intermediates of the reaction of an aliphatic nitro compound with a Grignard reagent. Such an intermediate might arise through initial reaction of the nitro compound in the aci form (or its conversion to the salt of the aci form by the Grignard reagent).

¹¹⁶ Gilman and McCracken, *J. Am. Chem. Soc.*, 49, 1052-61 (1927).

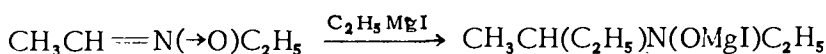


The only direct evidence bearing on this point is the statement (without supporting specifications) in an abstract of a paper by Wang¹¹⁷ to the effect that the initial product of the reaction of nitromethane with phenylmagnesium bromide is the nitronic salt $[\text{H}_2\text{C}=\text{N}(\rightarrow\text{O})\text{OMgBr}]$.

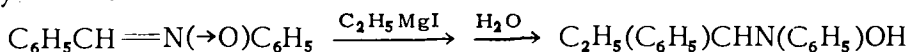
Assuming such an initial product, the formation of an isoöxime might take place as follows:



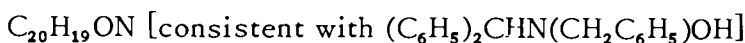
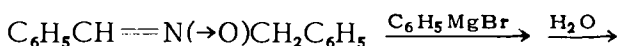
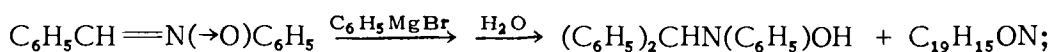
It is reasonable to suppose that an isoöxime might react with more Grignard reagent to form a hydroxylamine derivative.



For direct evidence on this point there is the statement of Angeli *et al.*¹¹⁸ that *N*-phenylisobenzaldoxime reacts with ethylmagnesium iodide to produce a compound of empirical formula $\text{C}_{15}\text{H}_{17}\text{ON}$, believed to be a hydroxylamine.

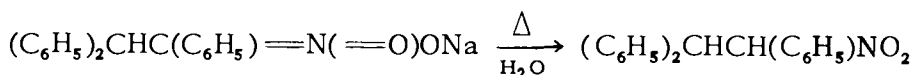


Similarly,



All these reactions would repay more detailed quantitative study with special precautions for the exclusion of oxygen and for the collection, definite identification, and measurement of evolved gases.

Kohler and Stone¹¹⁹ have reported the 1,4-addition of phenylmagnesium bromide to β -nitrostyrene to form an intermediate that is readily converted to a 90 percent yield of the sodium salt of the isonitro compound. Boiling in dilute aqueous solution converts the isonitro salt to the true nitro compound.



A similar experiment with methylmagnesium iodide yielded no well-defined product.

¹¹⁷ Wang, *Trans. Sci. Soc. China*, 7, 265-70 (1932); *Chem. Abstr.*, 26, 5545 (1932).

¹¹⁸ Angeli, Alessandri, and Mancini, *Atti accad. Lincei.*, [5], 20, 1, 546-55 (1911); *Chem. Zentr.*, 1911, 11, 606.

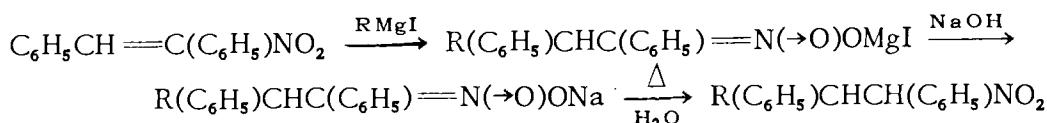
¹¹⁹ Kohler and Stone, *J. Am. Chem. Soc.*, 52, 761-8 (1930).

TABLE XIX-VIII
SOME REACTIONS OF GRIGNARD REAGENTS WITH α -NITRO OLEFINS

α -Nitro Olefin	RMgX	Product(s)
$\text{H}_2\text{C}=\text{CHNO}_2$ (11.2 g.)	$\text{C}_2\text{H}_5\text{MgBr}$ (50.0 g. $\text{C}_2\text{H}_5\text{Br}$)	$n\text{-C}_4\text{H}_9\text{NO}_2$ (3.2 g.); $\text{C}_2\text{H}_5(n\text{-C}_3\text{H}_7)\text{C}=\text{NOH}$ (4.7 g.); basic oil (4.8 g.); gas (4.4 l.)
$\text{H}_2\text{C}=\text{CHNO}_2$	$n\text{-C}_4\text{H}_9\text{MgBr}$ (excess)	$n\text{-C}_6\text{H}_{13}\text{NO}_2$ (43%); $n\text{-C}_4\text{H}_9(n\text{-C}_5\text{H}_{11})\text{C}=\text{NOH}$ (27.5%)
$\text{H}_2\text{C}=\text{CHNO}_2^*$	$n\text{-C}_4\text{H}_9\text{MgBr}$ (ca. 1 equiv., 0°)	$n\text{-C}_6\text{H}_{13}\text{NO}_2$ (65%)
$\text{CH}_3\text{CH}=\text{CHNO}_2$	$(\text{CH}_2)_5\text{CHMgBr}$	$\text{CH}_3[(\text{CH}_2)_5\text{CH}]\text{CHCH}_2\text{NO}_2$
$\text{H}_2\text{C}=\text{C}(\text{CH}_3)\text{NO}_2$	$\text{C}_2\text{H}_5\text{MgBr}$	$\text{CH}_3(n\text{-C}_3\text{H}_7)\text{CHNO}_2$
$(\text{CH}_3)_2\text{C}=\text{CHNO}_2$ (34.0 g.)	CH_3MgI (71.0 g. CH_3I)	$t\text{-C}_4\text{H}_9\text{CH}_2\text{NO}_2$ (16.2 g., 42%)
$(\text{CH}_3)_2\text{C}=\text{CHNO}_2$ (40.0 g.)	$\text{C}_2\text{H}_5\text{MgBr}$ (48.0 g. $\text{C}_2\text{H}_5\text{Br}$)	$\text{C}_2\text{H}_5(\text{CH}_3)_2\text{CCH}_2\text{NO}_2$ (60%)
$(\text{CH}_3)_2\text{C}=\text{CHNO}_2$ (34.0 g.)	$\text{C}_2\text{H}_5\text{MgI}$	$\text{C}_2\text{H}_5(\text{CH}_3)_2\text{CCH}_2\text{NO}_2$ (57.5%); $\text{C}_6\text{H}_{14}\text{O}_3\text{N}_2$ (0.4 g.)
$(\text{CH}_3)_2\text{C}=\text{CHNO}_2$ (20.0 g.)	$\text{H}_2\text{C}=\text{CHCH}_2\text{MgBr}$	$\text{H}_2\text{C}=\text{CHCH}_2(\text{CH}_3)_2\text{CCH}_2\text{NO}_2$ (6.5 g.)
$(\text{CH}_3)_2\text{C}=\text{CHNO}_2$ (10.0 g.)	$t\text{-C}_5\text{H}_{11}\text{MgCl}$	$t\text{-C}_5\text{H}_{11}(\text{CH}_3)_2\text{CCH}_2\text{NO}_2$ (6.5 g.)
$\text{CH}_3\text{CH}=\text{C}(\text{CH}_3)\text{NO}_2$ (20.0 g.)	$\text{C}_6\text{H}_5\text{MgBr}$	$\text{CH}_3(\text{C}_6\text{H}_5)\text{CHCH}(\text{CH}_3)\text{NO}_2$ (22.5 g., crude)
$\text{CH}_3\text{CH}=\text{C}(\text{CH}_3)\text{NO}_2$ (30.0 g.)	$n\text{-C}_{12}\text{H}_{25}\text{MgBr}$	$\text{CH}_3(n\text{-C}_{12}\text{H}_{25})\text{CHCH}(\text{CH}_3)\text{NO}_2$ (20.0 g.)
$(\alpha\text{-C}_4\text{H}_3\text{O})\text{CH}=\text{CHNO}_2^*$ (14.0 g.)	$n\text{-C}_4\text{H}_9\text{MgBr}$	$n\text{-C}_4\text{H}_9(\alpha\text{-C}_4\text{H}_3\text{O})\text{CHCH}_2\text{NO}_2^*$ (6.5 g.)
1-Nitrocyclohexene (32.0 g.)	$\text{C}_6\text{H}_5\text{CH}_2\text{MgBr}$	1-Nitro-2-benzylcyclohexane (23.5 g., crude)
$\text{C}_6\text{H}_5\text{CH}=\text{C}(\text{CH}_3)\text{NO}_2$ (32.0 g.)	$n\text{-C}_4\text{H}_9\text{MgBr}$	$n\text{-C}_4\text{H}_9(\text{C}_6\text{H}_5)\text{CHCH}(\text{CH}_3)\text{NO}_2$ (29.0 g.)

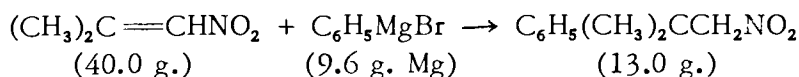
* $\alpha\text{-C}_4\text{H}_3\text{O} = 2\text{-furyl}$.

Methyl-, ethyl-, and benzylmagnesium iodides reacted with nitrostilbene to give 85–88 percent yields of the isonitro derivatives, which were converted to the nitro compounds in 95 percent yields.



According to Buckley,¹²⁰ the initial step in the reaction of an alkyl Grignard reagent with an α -nitro olefin is rapid 1,4-addition to the conjugated system $\text{C}=\text{CN}=\text{O}$ to form a complex which may be decomposed with water to yield a nitro paraffin, or which may react with more Grignard reagent to form a complex which, upon hydrolysis, yields an oxime. Simultaneously, some 1,2-addition to the nitro olefin occurs, to give a complex which, upon hydrolysis, yields basic products, "probably dialkylhydroxylamines." In many, though not in all, cases, inverse addition (*i.e.*, addition of the Grignard reagent to the nitro olefin) results in polymerization of the nitro olefin. The results of several experiments by Buckley (*loc. cit.*¹²⁰) and Buckley and Ellery¹²¹ are summarized in Table XIX-VIII.

Lambert *et al.*¹²² have also described the formation of a saturated nitro compound by the 1,4-addition of phenylmagnesium bromide to α -nitroisobutylene.



NITRITES AND NITRATES

The reactions of organic nitrites and nitrates with Grignard reagents appear to have been but little studied. Moureu¹²³ reported obtaining *N,N*-diethylhydroxylamine, in unspecified yield from the reaction of isobutyl nitrite with ethylmagnesium iodide. Sudborough *et al.*¹²⁴ state that organic nitrites, among other types of compounds, appear to be capable of forming additive complexes with Grignard reagents. Bewad¹²⁵ obtained *N,N*-di-*n*-propylhydroxylamine (in 25 percent yield) from the reaction of *n*-propylmagnesium iodide with isopropyl nitrite.

Alessandri¹²⁶ claims to have obtained a very small yield of 2-methyl-3-nitroindole from the reaction of 2-methylindolylmagnesium iodide and ethyl nitrate. Hepworth¹²⁷ investigated the reactions of methylmagnesium iodide and ethylmagnesium bromide with the nitric esters of ethanol,

¹²⁰ Buckley, *J. Chem. Soc.*, 1947, 1494–7.

¹²¹ Buckley and Ellery, *J. Chem. Soc.*, 1947, 1497–500.

¹²² Lambert, Rose, and Weedon, *J. Chem. Soc.*, 1949, 42–6.

¹²³ Moureu, *Compt. rend.*, 132, 837–9 (1901); *Chem. Zentr.*, 1901,1, 1000.

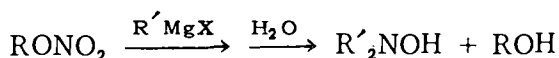
¹²⁴ Sudborough, Hibbert, and Beard, *Proc. Chem. Soc.*, 20, 165 (1904).

¹²⁵ Bewad, *Ber.*, 40, 3065–83 (1907).

¹²⁶ Alessandri, *Atti accad. Lincei*, [5], 24,11, 194–9 (1915); *Chem. Zentr.*, 1916,1, 1072.

¹²⁷ Hepworth, *J. Chem. Soc.*, 119, 251–60 (1921).

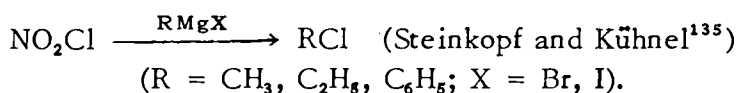
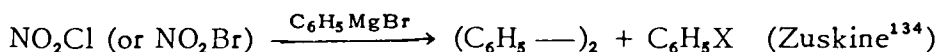
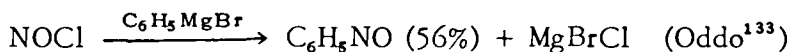
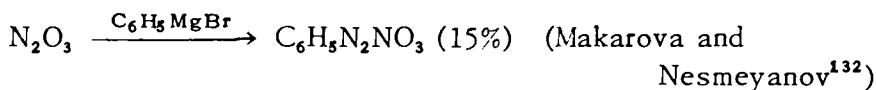
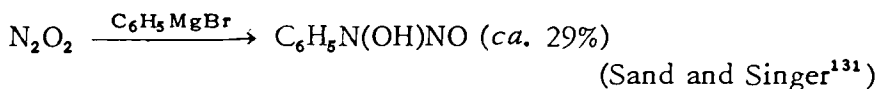
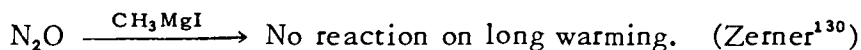
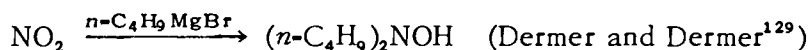
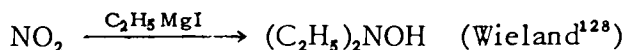
ethylene glycol, glycerol, and pentaerythritol. Although yields are not stated, the reactions are said to take the course:



In the case of ethyl nitrate and ethylmagnesium bromide a trace of diethylamine was also detected.

OXIDES AND HALO OXIDES OF NITROGEN

These reactants, also, have received but little attention; the recorded data follow.



N-HALOAMINES AND N-HALOIMINES

Buylla¹³⁶ reported that when *N*-iododiethylamine is subjected to the action of ethylmagnesium bromide the iodide is recovered quantitatively.

Strecker¹³⁷ recovered only ammonium salts from the reactions of nitrogen trichloride with ethylmagnesium bromide and iodide, respectively.

¹²⁸ Wieland, *Ber.*, 36, 2315-9 (1903).

¹²⁹ Dermer and Dermer, *J. Am. Chem. Soc.*, 64, 3056-7 (1942).

¹³⁰ Zerner, *Monatsh.*, 34, 1609-30 (1913).

¹³¹ Sand and Singer, *Ann.*, 329, 190-4 (1903).

¹³² Makarova and Nesmeyanov, *J. Gen. Chem. (U.S.S.R.)*, 9, 771-9 (1939); *Chem. Abstr.*, 34, 391 (1940).

¹³³ Oddo, *Gazz. chim. ital.*, 39, I, 659-61 (1909); *Chem. Zentr.*, 1909, II, 694.

¹³⁴ Zuskine, *Bull. soc. chim.*, [4], 37, 187 (1925).

¹³⁵ Steinkopf and Kühnel, *Ber.*, 75B, 1323-30 (1942).

¹³⁶ Buylla, *Rev. real. acad. cien., Madrid*, 9, 635-53, 718-34 (1910); *Chem. Abstr.*, 5, 3802 (1911).

¹³⁷ Strecker, *Ber.*, 43, 1131-6 (1910).

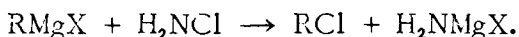
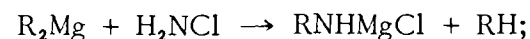
TABLE XIX-IX
REACTIONS OF MONOCHLORAMINE WITH GRIGNARD REAGENTS

<u>R (in RMgX)</u>	<u>X = Cl</u>		<u>X = Br</u>		<u>X = I</u>	
	<u>RNH₂(%)</u>	<u>NH₃(%)</u>	<u>RNH₂(%)</u>	<u>NH₃(%)</u>	<u>RNH₂(%)</u>	<u>NH₃(%)</u>
CH ₃	...	...	26.3	68.4	7.6	87.5
C ₂ H ₅	57.2	39.6	27.7	65.7	16.2	81.4
<i>n</i> -C ₃ H ₇	58.2	36.9	27.0	63.8	13.9	69.8
<i>i</i> -C ₃ H ₇	65.5	29.5	37.2	54.7	9.0	79.0
<i>n</i> -C ₄ H ₉	58.9	38.5	27.2	65.2	15.3	84.7
<i>s</i> -C ₄ H ₉	70.0	20.0	51.1	38.9	15.8	74.1
<i>t</i> -C ₄ H ₉	60.2	39.0	20.2	79.7	4.8	81.4
<i>i</i> -C ₈ H ₁₇	55.2	41.2	26.8	71.7	10.9	83.9
(C ₂ H ₅) ₂ CH	71.7	19.0	31.6	61.9	13.7	79.1
<i>t</i> -C ₈ H ₁₇	66.2	30.9	14.3	79.2	2.0	80.2
C ₆ H ₅	26.7	68.0	14.5	83.9	0.8	95.6
C ₆ H ₅ CH ₂	85.0	3.7	54.7	38.7	49.4	45.8
C ₆ H ₅ CH ₂ CH ₂	74.0	18.4	42.3	52.6	15.0	73.7

Le Févre¹³⁸ found that *N*-chloropiperidine reacts violently with phenylmagnesium bromide, but recovered only biphenyl from the reaction products. Upon reëxamination of this reaction, Le Févre¹³⁹ isolated 21 g. of crude chlorobenzene and 2.5 g. of biphenyl from the reaction (at 0°) of 42 ml. of *N*-chloropiperidine with a moderate excess of phenylmagnesium bromide solution. (The amount of biphenyl is, of course, within the probable limits of Wurtz byproduct in the Grignard reagent preparation.) Extending his exploration to other *N*-chloro compounds, Le Févre was able to isolate chlorobenzene as a product of the reaction of phenylmagnesium bromide with: monochloroamine, nitrogen trichloride, *N*-chlorodimethylamine, *N*-chlorodiethylamine, chloramine-T (*N*-chloro-*p*-toluenesulfonamide), and dichloramine-T.

A rather extensive investigation of the reactions of monochloroamine with Grignard reagents has been conducted by Coleman *et al.*¹⁴⁰ Their data are summarized in Table XIX-IX.

Coleman and Blomquist¹⁴¹ have assumed as a working hypothesis that the organomagnesium halide and the diorganomagnesium, with which it is presumably in Schlenk¹⁴² equilibrium, react differently with monochloroamine:



It is assumed that if any primary amine is formed directly from the organomagnesium halide, it is formed by some process stoichiometrically representable by:



As a test of this hypothesis they treated monochloroamine with the various *n*-butylmagnesium halides and with di-*n*-butylmagnesium under identical conditions in ethereal solution at 0°. Their data are summarized in Table XIX-X. When an equivalent of magnesium iodide was added to the di-*n*-butylmagnesium solution the yields of amine and ammonia were approximately the same as for *n*-butylmagnesium iodide. In ether-dioxane solution at -60° di-*n*-butylmagnesium gave a 97 percent yield of amine, with no ammonia detectable.

TABLE XIX-X

REACTIONS OF MONOCHLOROAMINE WITH $RMgX$ AND R_2Mg

Grignard reagent	RNH_2 (%)	NH_3 (%)
<i>n</i> -C ₄ H ₉ MgCl	57	43
<i>n</i> -C ₄ H ₉ MgBr	29	70
<i>n</i> -C ₄ H ₉ MgI	12	70
(<i>n</i> -C ₄ H ₉) ₂ Mg	82	14

¹³⁸ Le Févre, *J. Chem. Soc.*, 1932, 1376-9.

¹³⁹ Le Févre, *J. Chem. Soc.*, 1932, 1745-7.

¹⁴⁰ (a) Coleman and Hauser, *J. Am. Chem. Soc.*, 50, 1193-6 (1928); (b) Coleman and Yager, *ibid.*, 51, 567-9 (1929).

¹⁴¹ Coleman and Blomquist, *J. Am. Chem. Soc.*, 63, 1692-4 (1941).

¹⁴² Schlenk and Schlenk, *Ber.*, 62B, 920-4 (1929). (See Chapter IV.)

TABLE XIX-XI

REACTIONS OF VARIOUS *N*-MONOCHLORO- AND *N,N*-DICHLOROALKYLAMINES WITH GRIGNARD REAGENTS

Haloamine (RNHCl, R ₂ NCl, RNCI ₂)	Grignard Reagent (R'MgCl)	Prim. Amine (%) (RNH ₂)	Sec. Amine (%) (RR'NH, R ₂ NH)	Tert. Amine (%) (R'R ₂ N, RR' ₂ N)
CH ₃ NHCl	<i>n</i> -C ₄ H ₉ MgCl	72	14	—
CH ₃ NHCl	C ₆ H ₅ CH ₂ MgCl	70	14	—
C ₂ H ₅ NHCl	C ₆ H ₅ CH ₂ MgCl	75	12	—
(CH ₃) ₂ NCl (5°)	C ₆ H ₅ CH ₂ MgCl	—	95	5
(C ₂ H ₅) ₂ NCl (−10°)	C ₆ H ₅ CH ₂ MgCl	—	90	5
(C ₂ H ₅) ₂ NCl (5°)	C ₆ H ₅ CH ₂ MgCl	—	89	5
(C ₂ H ₅) ₂ NCl (40°)	C ₆ H ₅ CH ₂ MgCl	—	83	5
(C ₂ H ₅) ₂ NCl (70°)	C ₆ H ₅ CH ₂ MgCl	—	76	7
(<i>n</i> -C ₃ H ₇) ₂ NCl (5°)	C ₆ H ₅ CH ₂ MgCl	—	78	5
(<i>n</i> -C ₄ H ₉) ₂ NCl	<i>n</i> -C ₄ H ₉ MgCl	—	85	4
CH ₃ NCI ₂	<i>n</i> -C ₃ H ₇ MgCl	52	12	8
CH ₃ NCI ₂	<i>n</i> -C ₄ H ₉ MgCl	36	11	9
CH ₃ NCI ₂	<i>n</i> -C ₅ H ₁₁ MgCl	34	12	8
CH ₃ NCI ₂	C ₆ H ₅ CH ₂ MgCl	28	19	6
C ₂ H ₅ NCI ₂	<i>n</i> -C ₄ H ₉ MgCl	43	22	5
C ₂ H ₅ NCI ₂	C ₆ H ₅ CH ₂ MgCl	43	25	3

Coleman and Forrester¹⁴³ investigated the possibility of allylic rearrangement during the reaction of Grignard reagents with monochloroamine with negative results for the reagents tested. Their reported yields of "normal" primary amines for the respective Grignard reagents are: benzylmagnesium chloride, 92 percent; 1-naphthylmethylmagnesium chloride, 47 percent; cinnamylmagnesium chloride, 14 percent. These authors believe that if the isomeric amine was present in any case it was present as less than 1 percent of the reaction product.

Coleman¹⁴⁴ has also studied the reactions of Grignard reagents with *N*-chloroalkylamines, *N*-chlorodialkylamines, and *N,N*-dichloroalkylamines. His data are summarized in Table XIX-XI.

Similar data for nitrogen trichloride are presented in Table XIX-XII.¹⁴⁵

TABLE XIX-XII

REACTIONS OF NITROGEN TRICHLORIDE WITH GRIGNARD REAGENTS

<u>RMgX</u>	<u>RNH₂ (%)</u>	<u>R₂NH (%)</u>	<u>NH₃ (%)</u>
C ₂ H ₅ MgCl	29	6	22
C ₂ H ₅ MgBr	16	2	30
C ₂ H ₅ MgI	3	1	26
<i>i</i> -C ₃ H ₇ MgCl	23	2	23
<i>n</i> -C ₄ H ₉ MgCl	37	5	15
<i>n</i> -C ₄ H ₉ MgBr	21	2	20
<i>n</i> -C ₄ H ₉ MgI	4	1	31
<i>s</i> -C ₄ H ₉ MgCl	23	3	26
<i>s</i> -C ₄ H ₉ MgBr	10	1	31
<i>s</i> -C ₄ H ₉ MgI	3	1	26
<i>t</i> -C ₄ H ₉ MgCl	30	2	15
<i>n</i> -C ₅ H ₁₁ MgCl	21	5	21
C ₆ H ₅ MgCl	4	1	38
C ₆ H ₅ CH ₂ MgCl*	32	7	8
C ₆ H ₅ CH ₂ CH ₂ MgCl	20	2	27

* A trace of (C₆H₅CH₂)₃N was also detected in this reaction.

In the reactions of monochloroamine with Grignard reagents the evolution of nitrogen is negligible. With monobromoamine, however, there is appreciable nitrogen evolution.

The data of Coleman *et al.*¹⁴⁶ are summarized in Table XIX-XIII.

Like monobromoamine, dibromoamine evolves nitrogen in its reactions with Grignard reagents. Table XIX-XIV records the data of Coleman *et al.*¹⁴⁷

¹⁴³Coleman and Forrester, *J. Am. Chem. Soc.*, 58, 27-8 (1936).

¹⁴⁴Coleman, *J. Am. Chem. Soc.*, 55, 3001-5 (1933).

¹⁴⁵Coleman, Buchanan, and Paxson, *J. Am. Chem. Soc.*, 55, 3669-72 (1933). See also: Coleman and Buchanan, *Proc. Iowa Acad. Sci.*, 38, 168 (1931); *Chem. Abstr.*, 27, 1862 (1933).

¹⁴⁶Coleman, Soroos, and Yager, *J. Am. Chem. Soc.*, 55, 2075-80 (1933).

¹⁴⁷Coleman, Yager, and Soroos, *J. Am. Chem. Soc.*, 56, 965-6 (1934). See also: Coleman, Yager, and Soroos, *Proc. Iowa Acad. Sci.*, 40, 112 (1933).

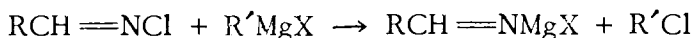
TABLE XIX-XIII
REACTIONS OF MONOBROMOAMINE WITH GRIGNARD REAGENTS

RMgX	RNH ₂ (%)	NH ₃ (%)	N ₂ (%)
<i>n</i> -C ₄ H ₉ MgCl	29	64	15
<i>n</i> -C ₄ H ₉ MgBr	9	78	7
<i>n</i> -C ₄ H ₉ MgI	3	89	8
<i>s</i> -C ₄ H ₉ MgCl	46	42	15
<i>t</i> -C ₄ H ₉ MgCl	45	22	5
<i>t</i> -C ₄ H ₉ MgBr	8	78	12
<i>t</i> -C ₄ H ₉ MgI	5	85	3
C ₆ H ₅ MgCl	4	85	11
C ₆ H ₅ CH ₂ MgCl	63	30	12
C ₆ H ₅ CH ₂ CH ₂ MgCl	34	51	6

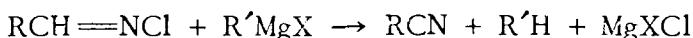
TABLE XIX-XIV
REACTIONS OF DIBROMOAMINE WITH GRIGNARD REAGENTS

RMgX	RNH ₂ (%)	R ₂ NH (%)	NH ₃ (%)	N ₂ (%)
<i>n</i> -C ₄ H ₉ MgCl	15	5	70	7
<i>n</i> -C ₄ H ₉ MgBr	5	1	89	—
<i>n</i> -C ₄ H ₉ MgI	2	0.4	95	1
<i>s</i> -C ₄ H ₉ MgCl	21	5	62	8
<i>t</i> -C ₄ H ₉ MgCl	24	5	53	9
<i>t</i> -C ₄ H ₉ MgBr	16	5	67	4
<i>t</i> -C ₄ H ₉ MgI	3	1	89	7
C ₆ H ₅ CH ₂ MgCl	34	6	41	4
C ₆ H ₅ CH ₂ CH ₂ MgCl	18	3	73	1

According to Le Maistre *et al.*,¹⁴⁸ the principal reaction of an *N*-chloroimine with a Grignard reagent is a metathetical exchange:



A competing, but relatively slow, reaction leads to nitrile formation.



Data are summarized in Table XIX-XV.

TABLE XIX-XV
REACTIONS OF *N*-CHLOROIMINES WITH GRIGNARD REAGENTS

RCH=NCl	R'MgX	Temp. (°C)	RCH=NH (%)	RCN (%)
2-ClC ₆ H ₄ CH=NCl	C ₂ H ₅ MgBr	-45	43	13
4-ClC ₆ H ₄ CH=NCl	C ₂ H ₅ MgBr	0	45	20
4-ClC ₆ H ₄ CH=NCl	C ₂ H ₅ MgBr	23-28	45	34
4-ClC ₆ H ₄ CH=NCl	4-ClC ₆ H ₄ MgBr*	0	18	5
4-ClC ₆ H ₄ CH=NCl	C ₆ H ₅ MgBr	0	61	10
2-CH ₃ OC ₆ H ₄ CH=NCl	C ₂ H ₅ MgBr	0	50	17

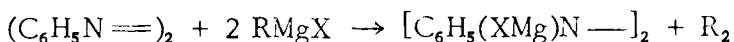
* A 25 percent yield of *p*-dichlorobenzene was obtained in this reaction.

¹⁴⁸ Le Maistre, Rainsford, and Hauser, *J. Org. Chem.*, 4, 106-10 (1939).

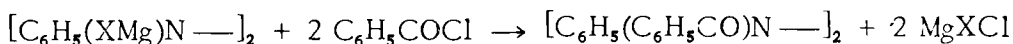
AZO COMPOUNDS

It was observed by Franzen and Deibel¹⁴⁹ that azobenzene reacts with two equivalents of ethylmagnesium bromide to yield hydrazobenzene and a gas which they assumed to be butane. Azo-*p*-toluene behaved similarly.

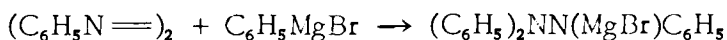
Gilman and Pickens¹⁵⁰ studied the reactions of azobenzene with various Grignard reagents. Gaseous products were not identified, but several Grignard reagent coupling products (*n*-octane, bicyclohexyl, biphenyl, and bi-*p*-tolyl) were isolated. Attempts to alkylate or acylate the dihalomagnesium derivative suggested by the reaction scheme



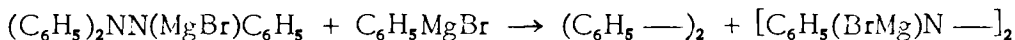
were partially successful in that some *sym.*-diphenyldibenzoylhydrazine was isolated when benzoyl chloride was used.



Busch and Hobein¹⁵¹ had suggested that azobenzene might be an intermediate in the conversion of phenylhydroxylamine to triphenylhydrazine by phenylmagnesium bromide; and that azobenzene might react additively with the Grignard reagent,

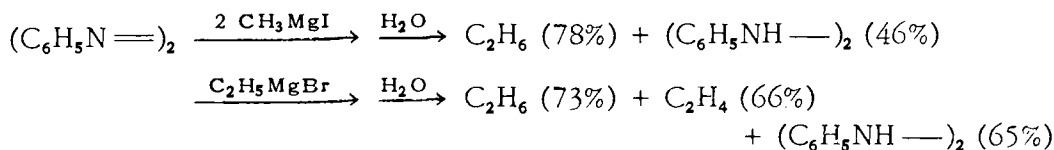


which would imply that the reduction of azobenzene by excess phenylmagnesium bromide should involve the improbable reaction:



Gilman and Adams¹⁵² went to the trouble to show that such a reaction does not, in fact, take place. When they treated triphenylhydrazine with excess phenylmagnesium bromide (or ethylmagnesium bromide), and hydrolyzed the resultant reaction mixture, the hydrazine was recovered almost quantitatively.

In a quantitative study Rheinboldt and Kirkberg¹⁵³ resolved any remaining doubts as to the course of such reduction reactions, and showed that the nature of the hydrocarbon product depends upon the nature of the reducing Grignard reagent. When the organic radical of the Grignard reagent is of a type that disproportionates readily, disproportion products are formed; when the radical is incapable of disproportionation, the coupling product is formed.



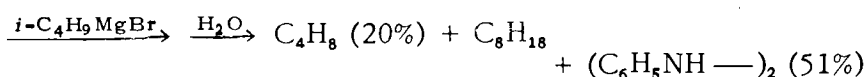
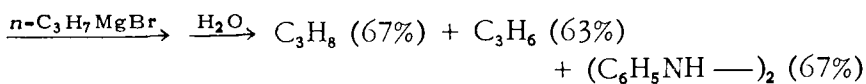
¹⁴⁹ Franzen and Deibel, *Ber.*, 38, 2716-8 (1905).

¹⁵⁰ Gilman and Pickens, *J. Am. Chem. Soc.*, 47, 2406-16 (1925).

¹⁵¹ Busch and Hobein, *Ber.*, 40, 2099-102 (1907).

¹⁵² Gilman and Adams, *J. Am. Chem. Soc.*, 48, 2004-5 (1926).

¹⁵³ Rheinboldt and Kirkberg, *J. prakt. Chem.*, [2], 118, 1-13 (1928).

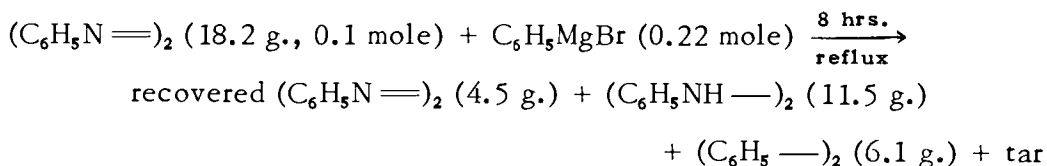
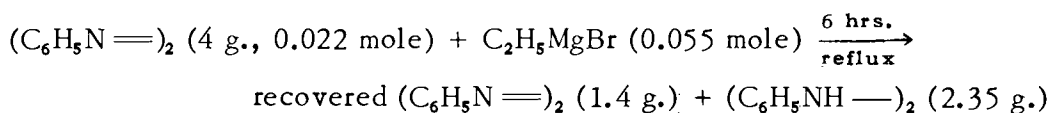


It has been shown by Gilman and Heck¹⁵⁴ and by Bachmann¹⁵⁵ that the same reduction is effected by magnesium-magnesium iodide. The latter obtained hydrazobenzene in 85–90 percent yields, together with a little aniline.

The relative rates of reaction of various Grignard reagents with azobenzene have been investigated by Gilman *et al.*,¹⁵⁶ who found that, in general: the aliphatic Grignard reagents (other than methyl) react most rapidly; the methyl reagents are intermediate in reaction rate; and the aryl reagents react slowly.

That the initial interaction of azo compound and Grignard reagent is complex formation is suggested by the visual observations (precipitation) of several authors. The initial precipitates formed by the combination of Grignard reagents with several hydroxylated azo compounds in ethereal solution have been investigated by Taurins.¹⁵⁷ Complexes of the following types (in which $\text{RMgX} = \text{CH}_3\text{MgI}$, $\text{C}_2\text{H}_5\text{MgBr}$, $\text{C}_6\text{H}_5\text{MgBr}$, $\text{C}_6\text{H}_5\text{MgI}$, $\text{C}_6\text{H}_5\text{CH}_2\text{MgCl}$) are reported: $\text{RMgX} \cdot \text{C}_6\text{H}_5\text{N}=\text{NC}_6\text{H}_4\text{-4-OH} \cdot (\text{Et}_2\text{O})_2$; $(\text{RMgX})_2 \cdot \text{C}_6\text{H}_5\text{N}=\text{NC}_{10}\text{H}_7\text{-1-OH} \cdot (\text{Et}_2\text{O})_n$; $\text{RMgX} \cdot (4\text{-HOC}_6\text{H}_4\text{N}=\text{N})_2 \cdot (\text{Et}_2\text{O})_2$. Also described are: $(\text{C}_6\text{H}_5)_2\text{Mg} \cdot (\text{C}_6\text{H}_5\text{N}=\text{NC}_6\text{H}_4\text{-4-OH})_2 \cdot (\text{Et}_2\text{O})_n$; $(\text{C}_6\text{H}_5)_2\text{Mg} \cdot \text{C}_6\text{H}_5\text{N}=\text{NC}_6\text{H}_4\text{-4-OH} \cdot (\text{Et}_2\text{O})_n$; $(\text{MgBr}_2)_2 \cdot (\text{C}_6\text{H}_5\text{N}=\text{NC}_6\text{H}_4\text{-4-OH})_3$; $\text{MgI}_2 \cdot (\text{C}_6\text{H}_5\text{N}=\text{NC}_6\text{H}_4\text{-4-OH})_2$.

The earlier literature has been reviewed by Gilman and Bailie,¹⁵⁸ who also contribute the following quantitative data:



A more recent study at the University of Chicago^{158,1} has shown that the interaction of pure azobenzene with ethereal phenylmagnesium bromide

¹⁵⁴ Gilman and Heck, *Rec. trav. chim.*, 50, 522–4 (1931).

¹⁵⁵ Bachmann, *J. Am. Chem. Soc.*, 53, 1524–31 (1931).

¹⁵⁶ Gilman, Heck, and St. John, *Rec. trav. chim.*, 49, 212–5 (1930).

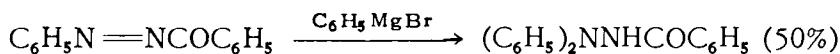
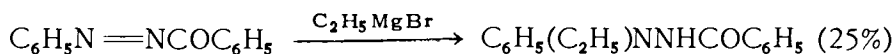
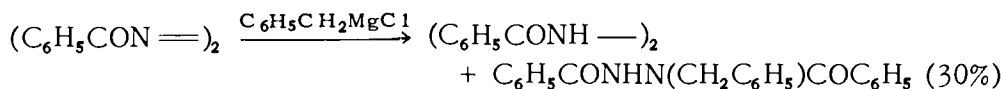
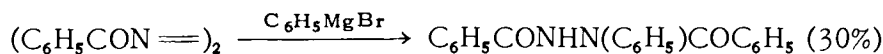
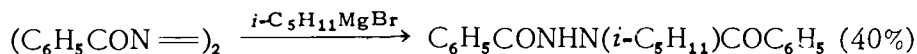
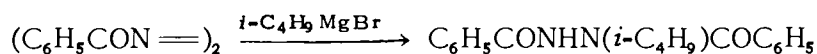
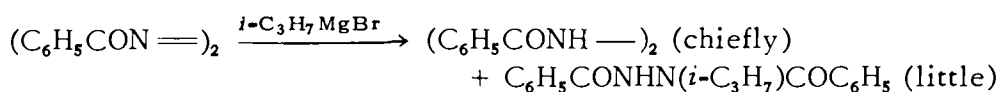
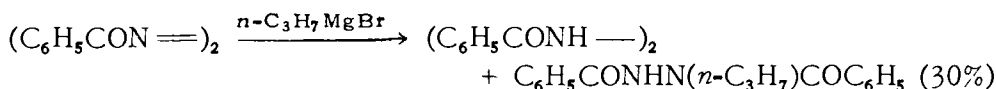
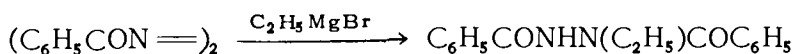
¹⁵⁷ Taurins, *Acta, Univ. Latviensis Kim. Fakult Serija*, 2, 321–8 (1934); *Chem. Abstr.*, 29, 1400 (1935).

¹⁵⁸ Gilman and Bailie, *J. Org. Chem.*, 2, 84–94 (1937).

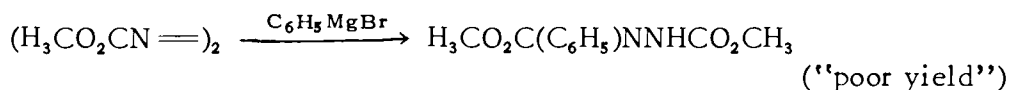
^{158,1} Kharasch, Matthews, and Nudenberg, unpublished work.

prepared from sublimed magnesium produces no biphenyl beyond that incidental to Grignard reagent preparation (4-6 percent). Under the same conditions phenylmagnesium bromide from ordinary magnesium turnings gave rise to 50-60 percent yields of biphenyl. Methylmagnesium bromide from either metallic source yielded ethane readily upon gentle warming of the ethereal reaction mixture.

Acyl azo compounds are reported to yield both the "normal" reduction products and addition products (Stollé and Reichert¹⁵⁹)



Also reported by Stollé and Reichert (*loc. cit.*¹⁵⁹):



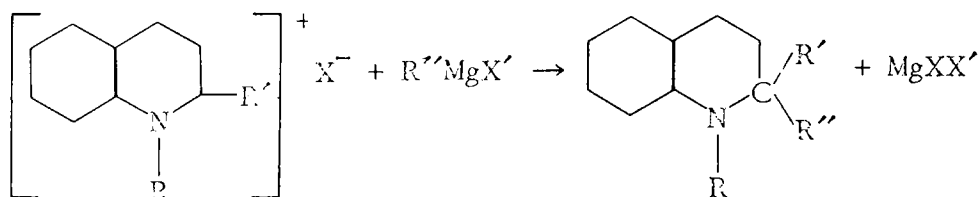
QUATERNARY SALTS

The reactions of quaternary salts with Grignard reagents were first investigated by Freund,¹⁶⁰ who reported on 1-methylquinolinium and 9-phenyl-10-methylacridinium iodides. These are in general metathetical reactions in which the positive halomagnesium ion of the Grignard reagent combines with the negative ion of the quaternary salt (or base) and the negative organic ion of the Grignard reagent attaches to some atom other than the quaternized nitrogen atom of the positive ion of the salt (or base), forming a covalent molecule.

For quinolinium salts the "normal" reaction appears to be that described by the general equation:

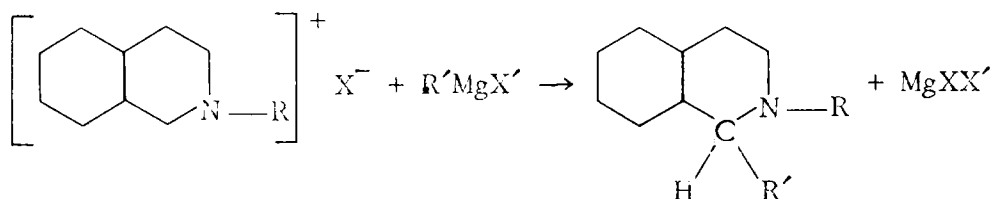
¹⁵⁹Stollé and Reichert, *J. prakt. Chem.*, [2], 122, 344-9 (1929).

¹⁶⁰Freund, *Ber.*, 37, 4666-72 (1904).

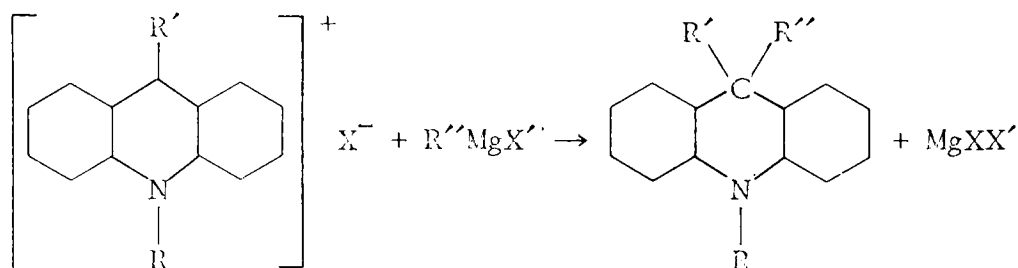


Such reactions are reported by: Freund (*loc. cit.*¹⁶⁰); Freund and Richard;¹⁶¹ and Craig.¹⁶²

Isoquinolinium salt reactions, as reported by Freund and Bode¹⁶³ and by Bergmann and Rosenthal,¹⁶⁴ are similar.

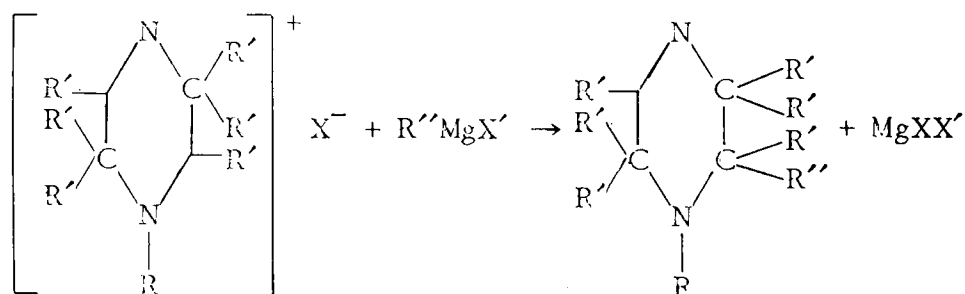


In the acridinium salt reactions bond formation takes place at the 9 position (Freund, *loc. cit.*¹⁶⁰; Freund and Bode, *loc. cit.*¹⁶³; Semon and Craig¹⁶⁵).



The benz[*a*]acridinium salt reactions are similar, bond formation taking place at the 12 position (Freund and Bode, *loc. cit.*¹⁶³).

2,4-Dihydropyrazinium salts (and bases) have been found by Aston *et al.*¹⁶⁶ to form 6-substituted 1,2,4,6-tetrahydropyrazines.



The quinoxalinium salt reactions appear to be similar (Freund and Richard, *loc. cit.*¹⁶¹).

¹⁶¹ Freund and Richard, *Ber.*, 42, 1101-21 (1909).

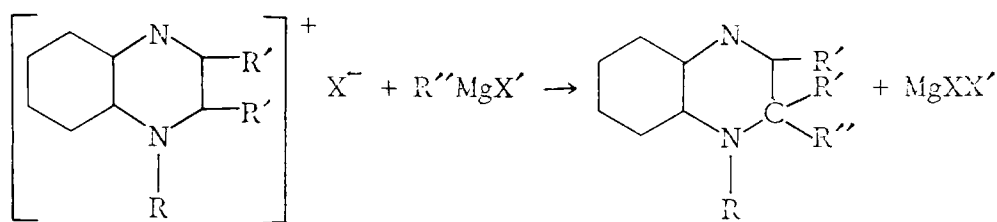
¹⁶² Craig, *J. Am. Chem. Soc.*, 60, 1458-65 (1938).

¹⁶³ Freund and Bode, *Ber.*, 42, 1746-66 (1909).

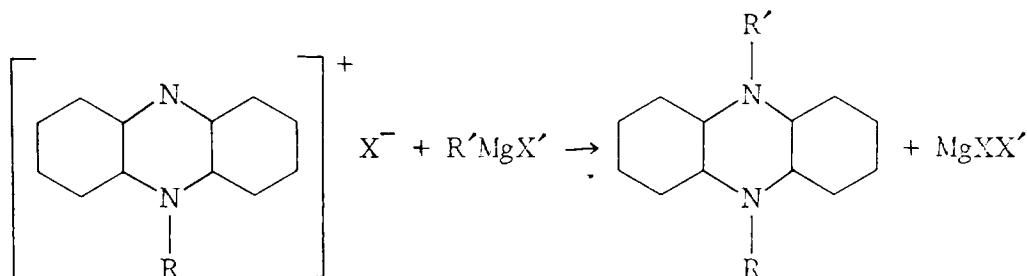
¹⁶⁴ Bergmann and Rosenthal, *J. prakt. Chem.*, [2], 135, 267-81 (1932).

¹⁶⁵ Semon and Craig, *J. Am. Chem. Soc.*, 58, 1278-82 (1936).

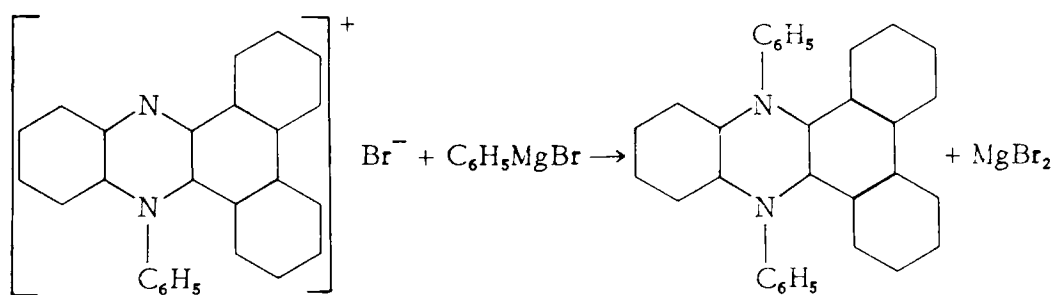
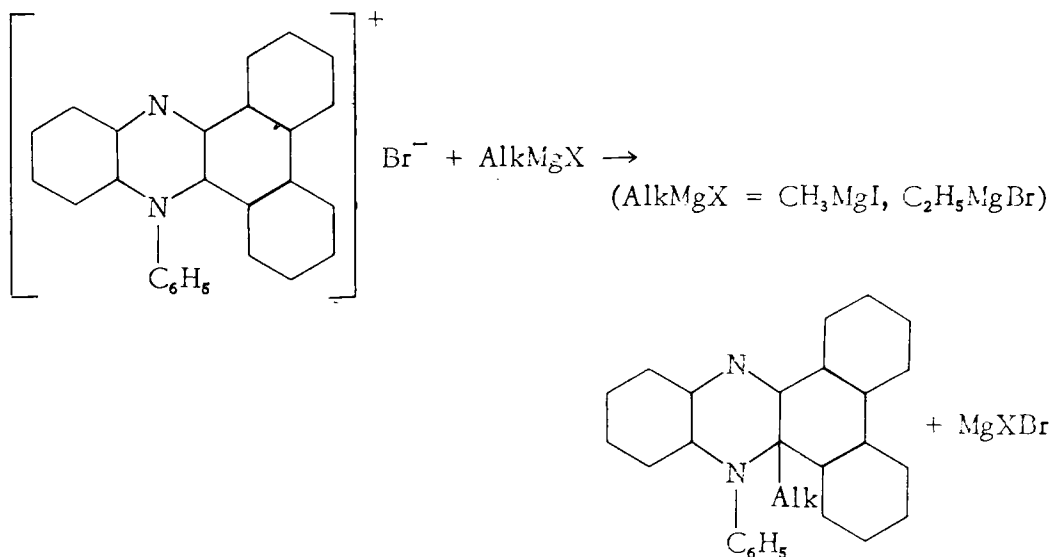
¹⁶⁶ Aston, Ailman, Scheuermann, and Koch, *J. Am. Chem. Soc.*, 56, 1163-6 (1934).



Phenazinium salts undergo 10-addition (Hilleman;¹⁶⁷ McIlwain¹⁶⁸).



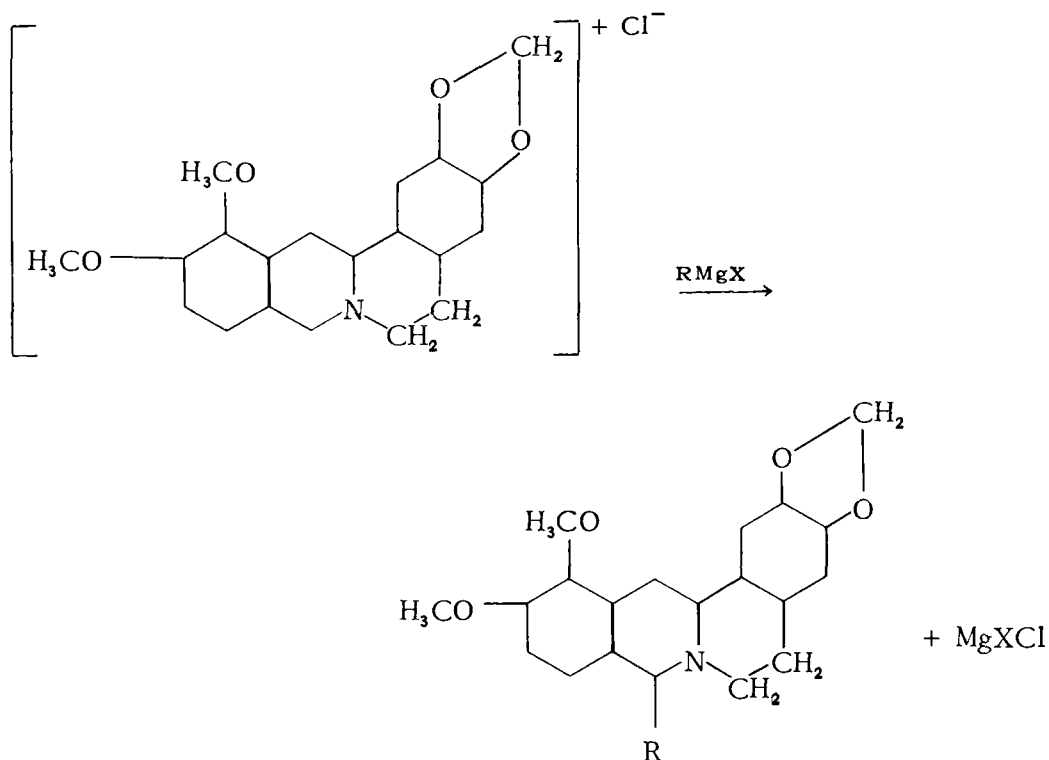
Dibenzo[ac]phenazinium salts (specifically, flavinduline bromide) are reported to undergo α - (*i.e.*, 8b-) substitution with alkyl Grignard reagents, N- (*i.e.*, 14-) substitution with aryl Grignard reagents, and a combination of the two with benzylmagnesium chloride (Freund and Richard, *loc. cit.*¹⁶¹).



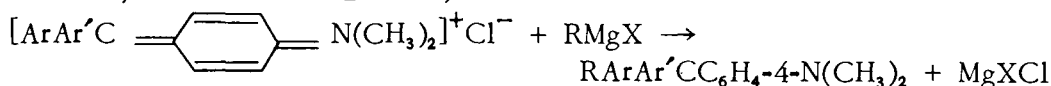
¹⁶⁷ Hilleman, *Ber.*, 71B, 42-6 (1938).

¹⁶⁸ McIlwain, *J. Chem. Soc.*, 1937, 1704-11.

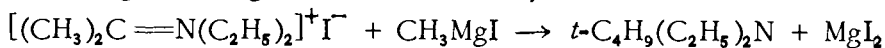
With benzylmagnesium chloride, berberine hydrochloride reacts to give a nearly quantitative yield of 2,3-methylenedioxy-8-benzyl-11,12-dimethoxy-5,6-dihydrodibenzo[ag]quinolazine (Freund and Beck¹⁶⁹). The reactions with methylmagnesium iodide and phenylmagnesium bromide are similar.



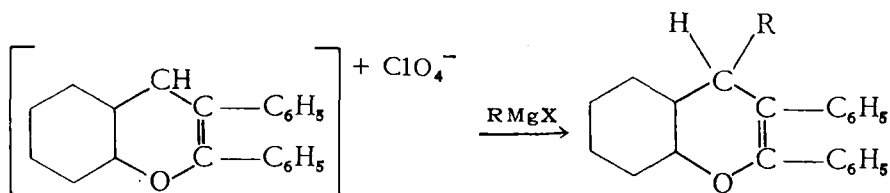
Salts of the "triphenylmethane dye" type (crystal violet, brilliant green) undergo addition at the methane carbon atom (Freund and Richard, *loc. cit.*;¹⁶¹ Freund and Beck¹⁷⁰).



According to Reiber and Stewart,¹⁷¹ tetraalkylmethylenimmonium salts react with Grignard reagents to form tertiary amines.



The foregoing reactions bear a marked resemblance to the pyrrilium salt reactions described by Löwenbein and Rosenbaum.¹⁷²

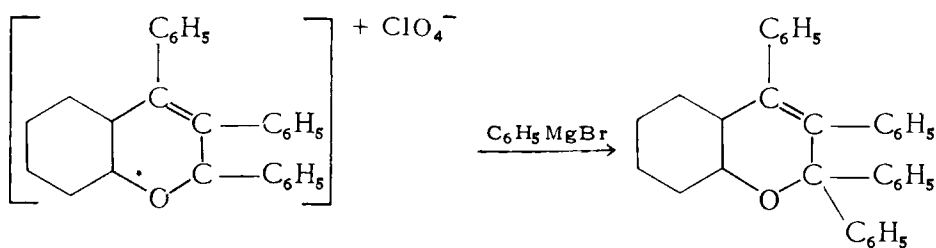


¹⁶⁹ Freund and Beck, *Ber.*, 37, 4673-9 (1904).

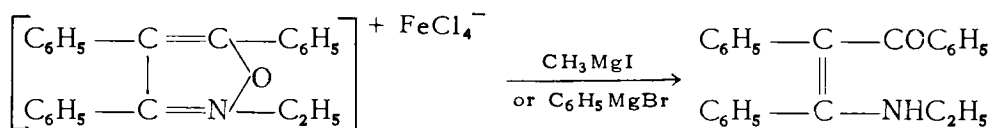
¹⁷⁰ Freund and Beck, *Ber.*, 37, 3679-80 (1904).

¹⁷¹ Reiber and Stewart, *J. Am. Chem. Soc.*, 62, 3026-30 (1940).

¹⁷² Löwenbein and Rosenbaum, *Ann.*, 448, 223-48 (1926).

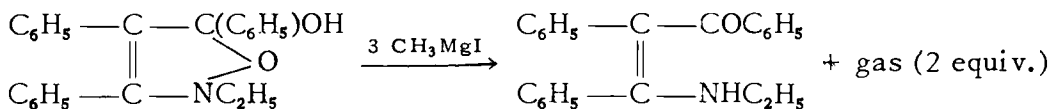


A reductive isoxazolinium salt reaction is described by Kohler and Richtmyer.¹⁷³



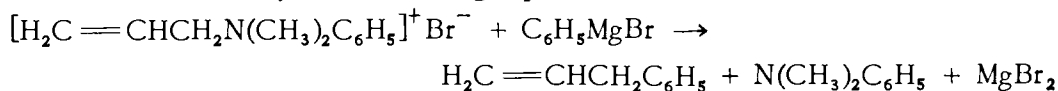
The corresponding chloride reacts very slowly with methylmagnesium iodide and not at all with phenylmagnesium bromide.

The corresponding pseudobase undergoes a similar reduction (Kohler and Richtmyer, *loc. cit.*¹⁷³).



Proof addendum. Work still in progress at The University of Chicago^{173.1} at this writing suggests that the gramine methiodide-Grignard reagent reactions of Snyder *et al.*^{173.2} are special cases of a general allylic phenomenon that invites further study.

Apparently the presence of an allylic grouping among the quaternary nitrogen substituents is a necessary, but not always a sufficient, predisposing factor in reactions of this type. For example, phenylmagnesium bromide prepared from sublimed magnesium cleaves allylphenyldimethylammonium bromide under relatively mild experimental conditions in the manner indicated by the following equation:



Under the same conditions allyltrimethylammonium bromide is unaffected by phenylmagnesium bromide prepared from sublimed magnesium, but undergoes cleavage when "catalytic" quantities of cobalt, nickel, or iron salts are added to the reaction system.

AMMONIA, AMINES, HYDRAZINES, AND TRIAZENES

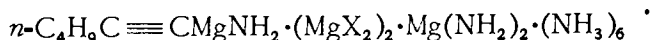
For the most part, ammonia and the simple primary and secondary amines behave toward Grignard reagents as "active hydrogen" compounds

¹⁷³ Kohler and Richtmyer, *J. Am. Chem. Soc.*, 50, 3092-106 (1928).

^{173.1} Kharasch, Williams, and Nudenberg, unpublished work.

^{173.2} Snyder, Eliel, and Carnahan, *J. Am. Chem. Soc.*, 73, 970-3 (1951). *Cf.* Geissmann and Armen, *ibid.*, 74, 3916-9 (1952).

(*q.v.*, Chapter XVIII), and form so-called "nitrogen Grignard reagents." According to Hennion and Wolf,¹⁷⁴ ammonia decomposes *n*-butylethynyl-magnesium bromide or chloride and forms complex amorphous precipitates to which they attribute the composition



For reactions of Grignard reagents with cyclic secondary amines (such as pyrrole, indole, etc.), which form compounds that behave for the most part like "true" Grignard reagents, consult Chapter II on Preparation of Grignard Reagents. Concerning Grignard reagent complex formation with tertiary amines see the same chapter.

The special case of the alkoxymethyl tertiary amines ($\text{R}_2\text{NCH}_2\text{OR}'$) is discussed in Chapter XV on Ethers, etc. (*q.v.*).

Puxeddu¹⁷⁵ reports that 3-amino-*p*-cresol and "amino- β -naphthol" evolve no gas when treated with ethylmagnesium iodide, but form yellowish-brown precipitates of the general composition $\text{R}(\text{OH})\text{NH}_2\cdot(\text{R}'\text{MgX})_2$. The precipitates so formed, when treated with acetyl chloride, evolve ethane and form acetyl derivatives.

According to Gilman and Adams,¹⁷⁶ triphenylhydrazine, treated with ethyl- or phenylmagnesium bromide, yields an intermediate from which, upon hydrolysis, most of the hydrazine may be recovered unchanged.

Meunier¹⁷⁷ observed evolution of ethane and formation of iodomagnesyl derivatives when hydrazobenzene and α,γ -diphenyltriazene, respectively, were treated with ethylmagnesium iodide.

Bachmann¹⁷⁸ reports that treatment of hydrazobenzene with ethylmagnesium iodide yields a di(iodomagnesyl) derivative identical with that formed by the addition of magnesious iodide ($\text{Mg} + \text{MgI}_2$) to azobenzene.

Grammaticakis¹⁷⁹ found, however, that α -acyl- β -phenylhydrazines do not react with Grignard reagents in ethereal solution. Treatment of α -acetyl- β -phenylhydrazines with phenylmagnesium bromide at 116–120° for seven to twelve hours yielded 2-phenylindole, together with a little acetophenone and acetophenone phenylhydrazone. α -Formyl- β -phenylhydrazine, similarly treated, yields benzophenone, together with a little benzophenone anil and benzophenone phenylhydrazone. α -Benzoyl- β -phenylhydrazine yields benzophenone phenylhydrazone, benzophenone anil, benzophenone imine, and benzophenone. In all cases traces of aniline and phenylhydrazine were detected.

According to Wuyts and Lacourt,¹⁸⁰ 1-methyl-1-thiobenzoyl-2-phenylhydrazine is reduced by ethylmagnesium bromide.

¹⁷⁴Hennion and Wolf, *Proc. Indiana Acad. Sci.*, 48, 98–101 (1939); *Chem. Abstr.*, 33, 6794 (1939).

¹⁷⁵Puxeddu, *Gazz. chim. ital.*, 53, 99–105 (1923); *Chem. Zentr.*, 1924, I, 1923.

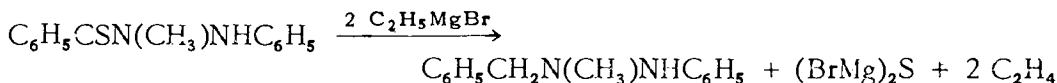
¹⁷⁶Gilman and Adams, *J. Am. Chem. Soc.*, 48, 2004–5 (1926).

¹⁷⁷Meunier, *Compt. rend.*, 136, 758–9 (1903); *Chem. Zentr.*, 1903, I, 1024.

¹⁷⁸Bachmann, *J. Am. Chem. Soc.*, 53, 1524–31 (1931).

¹⁷⁹Grammaticakis, *Compt. rend.*, 207, 239–41 (1938); *Chem. Abstr.*, 34, 2808 (1940).

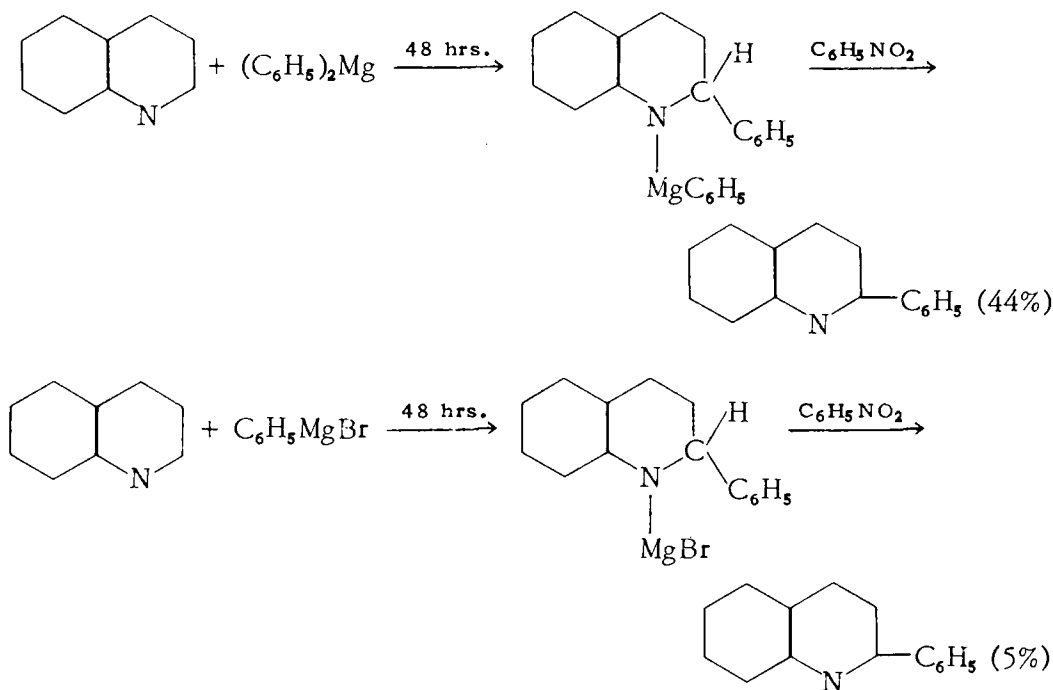
¹⁸⁰Wuyts and Lacourt, *Bull. soc. chim. Belg.*, 44, 395–410 (1935).



The arylation or alkylation of cyclic amines by Grignard reagents has been reported by various authors. The reactions appear to consist in complex formation, with subsequent rearrangement to form an addition compound. (For discussions of reaction mechanism see: Bergstrom and McAllister¹⁸¹ and Tch  oufaki and Kwang-liang.¹⁸²) Generally speaking, dihydro derivatives of the type formed upon hydrolysis lose hydrogen very readily (probably by autoxidation), but in a few cases the isolation of the dihydro derivatives has been reported.

Oddo¹⁸³ found that 2-phenylquinoline is formed (apparently in small yield) either when (a) a mixture of magnesium (6 g.), quinoline (32 g.), bromobenzene (40 g.), and toluene (50 ml.) is heated in an oil-bath at 140°, or when (b) a mixture of phenylmagnesium bromide (18 g.), quinoline (12.9 g.), and pyridine (8.9 g.) is refluxed for two hours. Bergstrom and McAllister (*loc. cit.*¹⁸¹) autoclaved quinoline in ethereal phenylmagnesium bromide at 150–160° for three hours and obtained a 66 percent yield of crude 2-phenylquinoline.

According to Gilman and Gainer,¹⁸⁴ the room-temperature reaction of diphenylmagnesium with quinoline is materially faster than the corresponding reaction of phenylmagnesium bromide.



¹⁸¹ Bergstrom and McAllister, *J. Am. Chem. Soc.*, 52, 2845–9 (1930).

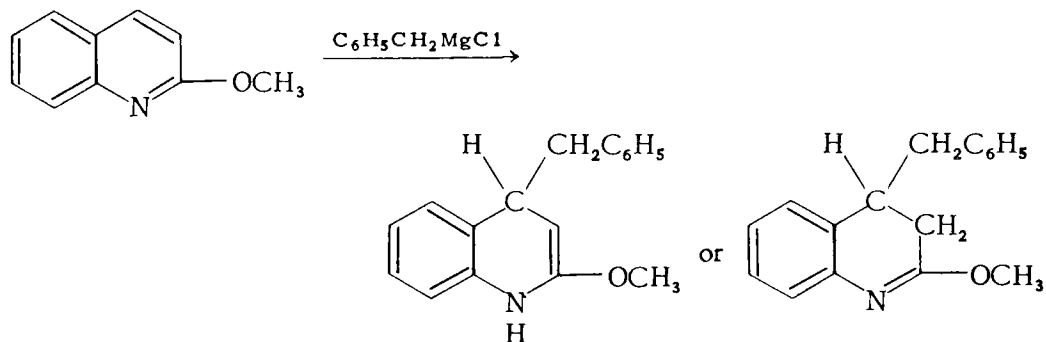
¹⁸² Tch  oufaki and Kwang-liang, *Sci. Record (China)*, 2, 70–4 (1947); *Chem. Abstr.*, 42, 2605 (1948).

¹⁸³ Oddo, *Atti accad. Lincei*, [5], 16, I, 413–8 (1907); *Chem. Zentr.*, 1907, I, 1543; *Atti accad. Lincei*, [5], 16, I, 538–45 (1907); *Chem. Zentr.*, 1907, II, 73; *Gazz. chim. ital.*, 37, I, 568–76 (1907); *Chem. Zentr.*, 1907, II, 612.

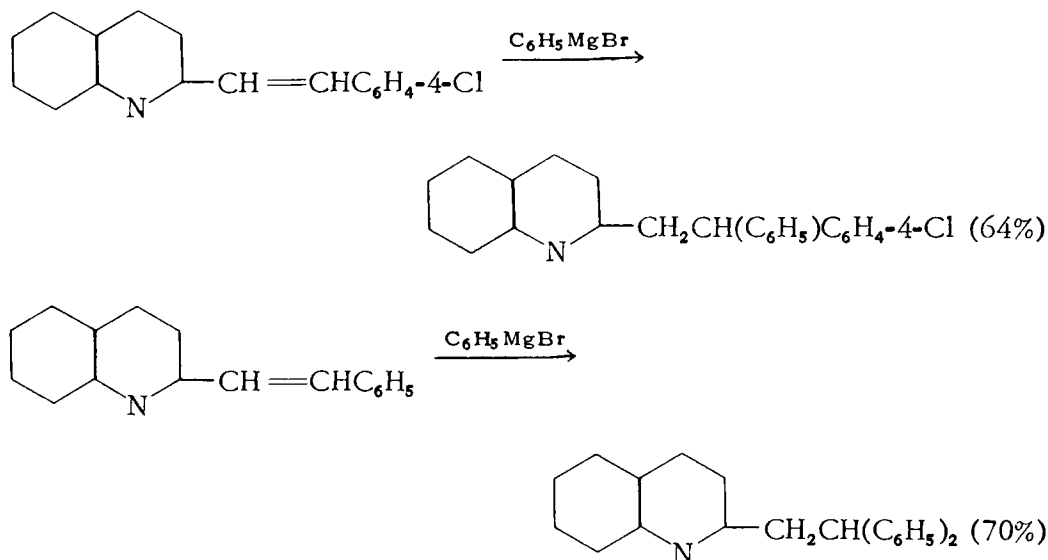
¹⁸⁴ Gilman and Gainer, *J. Am. Chem. Soc.*, 71, 2327–8 (1949).

It is conceivable that the apparent difference in the behavior of the two reagents is not altogether what it appears. If this is essentially a reaction of the radical type, peroxidic materials introduced in the dioxane involved in diphenylmagnesium preparation might play a significant part.

Fuson *et al.*^{184,1} have found that reaction of benzylmagnesium chloride with 2-methoxyquinoline leads, not to replacement of the methoxyl group, as might have been expected, but to formation of the 4-benzyl derivative of 2-methoxy-1,4-(or 3,4-)dihydroquinoline.



1,4-Addition to α -benzylidenequinaldines is reported by Hoffman *et al.*¹⁸⁵



Autoclave treatment of pyridine with ethyl- and phenylmagnesium bromides gave 2-ethyl- and 2-phenylpyridine in 45 and 44 percent yields, respectively (Bergstrom and McAllister, *loc. cit.*¹⁸¹). By shaking pyridine with benzylmagnesium chloride in ethereal solution containing a little dioxane for twenty-four hours, Bergmann and Rosenthal¹⁸⁶ obtained a small (*ca.* 7.5 percent) yield of a derivative which they designated as 2-benzylpyridine. Their identification has been questioned by Veer and

^{184,1} Fuson, Jackson, and Grieshaber, *J. Org. Chem.*, 16, 1529-35 (1951).

¹⁸⁵ Hoffman, Farlow, and Fuson, *J. Am. Chem. Soc.*, 55, 2000-4 (1933).

¹⁸⁶ Bergmann and Rosenthal, *J. prakt. Chem.*, [2], 135, 267-81 (1932).

St. Goldschmidt,¹⁸⁷ who, after twenty-four hours refluxing of an ethereal solution of pyridine and benzylmagnesium chloride, isolated an 8.5 percent yield of a derivative which they identified as 4-benzylpyridine.

By shaking quinoline (10.3 g.) for two days with ethereal benzylmagnesium chloride containing dioxane (15 ml.), Bergmann and Rosenthal (*loc. cit.*¹⁸⁶) obtained a mixture of 2-phenylquinoline (6.5 g.), 4-phenylquinoline (0.8 g.), and 2,4-diphenylquinoline (1.4 g.).

Similar treatment of isoquinoline (10.3 g.) yielded 1-benzyl-1,2-dihydroisoquinoline (11.0 g.) (Bergmann and Rosenthal, *loc. cit.*¹⁸⁶). By autoclaving isoquinoline with ethereal ethylmagnesium bromide at 150–160° for three hours, Bergstrom and McAllister (*loc. cit.*¹⁸¹) obtained 1-ethylisoquinoline in 66 percent yield.

Acridine (15.6 g.) shaken with ethereal benzylmagnesium chloride and dioxane for two days yielded 9-benzyl-9,10-dihydroacridine (4.0 g.) and 9-benzylacridine (Bergmann and Rosenthal, *loc. cit.*¹⁸⁶). By treatment of acridine with methylmagnesium iodide in a manner not specifically described, Bergmann and Haskelberg¹⁸⁸ obtained 5,10-dimethyl-5,10-dihydroacridine.

Etienne¹⁸⁹ observed no reaction of 1-azanthracene (benzo[g]quinoline) in cold ethereal solution, but in benzene obtained 9-phenyl-1-azanthracene. The 9-chloro derivative behaved similarly. When the bromomagnesyl intermediate obtained from the latter was treated with acetyl chloride, however, an acetyl derivative of 2-phenyl-9-chloro-1,2-dihydro-1-azanthracene was isolated.

Ethylmagnesium bromide is reported as reacting (presumably in autoclave) with nicotine, cinchonine, 2-picoline, quinaldine, and 4,4'-bipyridyl, but the products were not identified (Bergstrom and McAllister, *loc. cit.*¹⁸¹).

Lukeš¹⁹⁰ added *N*-methylpyrrolidine (50 g.) dropwise to an ethereal solution of methylmagnesium bromide (from 36 g. magnesium) and allowed the mixture to stand for twenty-four hours. During the reaction 8.4 l. of gas (90 percent methane) was evolved. 1,2-Dimethyl- Δ^2 -pyrroline and 1,2,3-trimethylpyrrolidine were isolated. In similar reactions ethylmagnesium and *n*-propylmagnesium bromides yielded 1-methyl-2-alkyl- Δ^2 -pyrrolines and 1-methyl-2,2-dialkylpyrrolidines. From a reaction with phenylmagnesium bromide only 1-methyl-2-phenyl- Δ^2 -pyrroline was isolated.

According to Hoshino¹⁹¹ 3-(β -aminoethyl)indole, treated with four equivalents of methylmagnesium iodide forms "dinordesoxyeseroline" in 30 percent yield. The corresponding 2-methyl derivative, similarly treated, yields "dinordesoxy-9-methyleseroline."

¹⁸⁷ Veer and St. Goldschmidt, *Rec. trav. chim.*, 65, 793–5 (1946).

¹⁸⁸ Bergmann and Haskelberg, *J. Chem. Soc.*, 1939, 1–5.

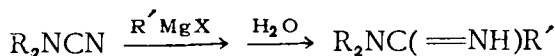
¹⁸⁹ Etienne, *Compt. rend.*, 219, 622–4 (1944); *Chem. Abstr.*, 40, 1513 (1946).

¹⁹⁰ Lukeš, *Chem. Listy*, 27, 97–100, 121–5 (1933); *Chem. Abstr.*, 27, 5323 (1933).

¹⁹¹ Hoshino, *Abstracts of Japan Chem. Lit.*, 6, 390–1 (1932); *Chem. Abstr.*, 27, 291 (1933).

CYANAMIDES

So far as the available evidence extends the cyanamides appear to undergo, for the most part, the "normal" addition reactions of cyano compounds (*q.v.*, Chapter X).



From phenylcyanamide and phenylmagnesium bromide Busch and Hobein¹⁹² obtained somewhat less than a 20 percent yield of *N*-phenylbenzamidine. α -Naphthylmagnesium bromide yielded only a trace of *N*-phenylnaphthoamidine.

Adams and Beebe¹⁹³ treated 12 g. of dibenzylcyanamide with ethylmagnesium bromide, and isolated 15 g. of crude *N,N*-dibenzylpropionamidine hydrochloride. Phenyl- and *p*-tolylmagnesium bromides reacted similarly to form the respective amidines in 70 percent, or better, yields.

Vuylsteke¹⁹⁴ reports the reaction of dimethylcyanamide with phenylmagnesium bromide to form *N,N*-dimethylbenzamidine. In a similar reaction benzylmagnesium chloride reacted to produce not only the amidine, but the cleavage products, benzyl cyanide and dimethylamine, as well. Vuylsteke did not succeed in separating the products of the ethylmagnesium bromide reaction.

ISONITRILES (CARBYLAMINES)

The formation of benzaldehyde by the action of phenylmagnesium bromide on methylcarbylamine (methyl isocyanide) was reported by Sachs and Loevy.¹⁹⁵ Gilman and Heckert,¹⁹⁶ however, were able to isolate only traces of benzaldehyde from the same reaction. From ethylcarbylamine they obtained no identifiable product. *t*-Butylcarbylamine yielded a little benzamide, a little benzophenone, and triphenylcarbinol (23.7 percent). *p*-Tolylcarbylamine gave a tarry reaction product in which only small amounts of *p*-toluidine were identified.

MISCELLANEOUS UNCLASSIFIED NITROGEN COMPOUNDS

Tarbell and Fukushima¹⁹⁷ treated 1,1-dimethylethyleneimine successively with a Grignard reagent and methyl *p*-chloromethylbenzoate in an attempt to alkylate the nitrogen atom, but without success. Treatment of 1,1-dimethyl-2- β -cyanoethylethyleneimine with methyl or phenyl Grignard reagents led only to the formation of polymeric material.

¹⁹² Busch and Hobein, *Ber.*, 40, 4296-9 (1907).

¹⁹³ Adams and Beebe, *J. Am. Chem. Soc.*, 38, 2768-72 (1916).

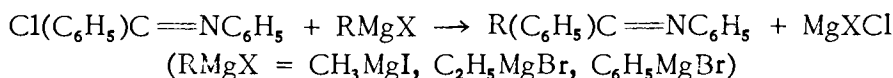
¹⁹⁴ Vuylsteke, *Bull. sci. acad. roy. Belg.*, [5], 12, 535-44 (1926); *Chem. Abstr.*, 21, 1108 (1927).

¹⁹⁵ Sachs and Loevy, *Ber.*, 37, 874-8 (1904).

¹⁹⁶ Gilman and Heckert, *Bull. soc. chim.*, [4], 43, 224-30 (1928).

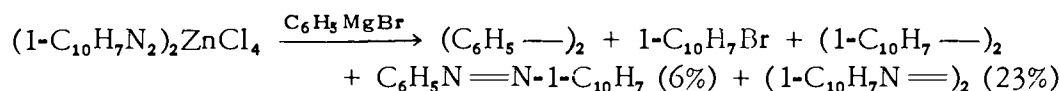
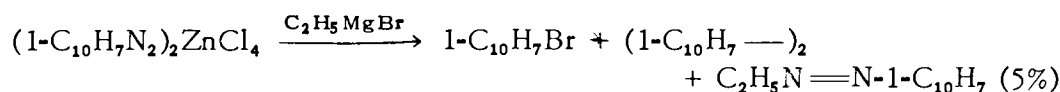
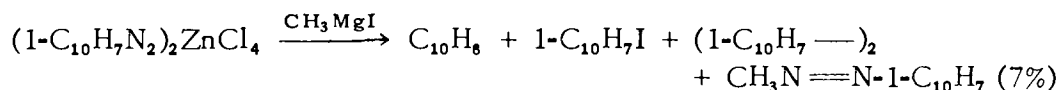
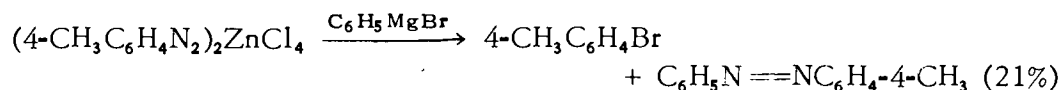
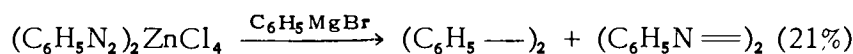
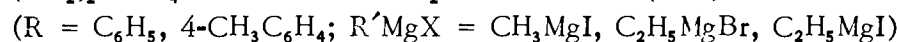
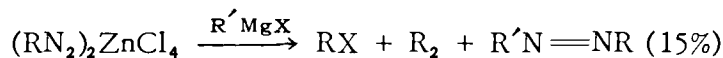
¹⁹⁷ Tarbell and Fukushima, *J. Am. Chem. Soc.*, 68, 2499-502 (1946).

According to Busch and Fleischmann¹⁹⁸ α -chlorobenzylideneaniline behaves toward Grignard reagents like an alkyl halide, although the reaction mechanism is doubtless quite different.



Mousseron and Winternitz¹⁹⁹ fused α -chlorocyclohexylamine with ethylmagnesium bromide and obtained cyclohexanone. The *N*-methyl, *N*-ethyl, and *N*-*n*-butyl derivatives behaved similarly, but the *N,N*-dimethyl compound did not react.

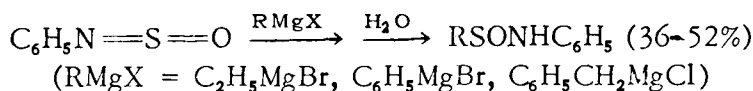
The reactions of several diazonium salts with ethereal Grignard reagents have been investigated by Hodgson and Marsden.²⁰⁰



According to Backhouse and Dwyer²⁰¹ the pyridine-coördinated iodine salt of *m,p'*-dinitro-1,3-diphenyltriazene reacts with methylmagnesium iodide to form the metallic salt of the triazene.

Wuyts and Lacourt²⁰² treated the following 2,3-dihydro-1,3,4-thiodiazoles with five molecular equivalents of methylmagnesium iodide and recovered them completely unchanged: 3,5-diphenyl-, 2-methyl-3,5-diphenyl-, 2,5-dimethyl-3-phenyl-, 2-methyl-3-*p*-tolyl-5-*o*-tolyl-. The 2,3,5-triphenyl-derivative was similarly unaffected by ethylmagnesium bromide.

Sonn and Schmidt²⁰³ report that thionylaniline reacts additively with Grignard reagents to form sulfinanilides.



¹⁹⁸ Busch and Fleischmann, *Ber.*, 43, 2553-6 (1910).

¹⁹⁹ Mousseron and Winternitz, *Compt. rend.*, 221, 701-3 (1945).

²⁰⁰ Hodgson and Marsden, *J. Chem. Soc.*, 1945, 274-6.

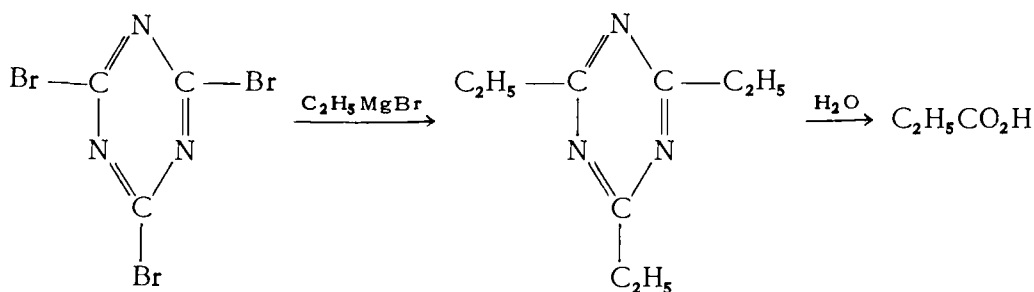
²⁰¹ Backhouse and Dwyer, *J. Proc. Roy. Soc., N. S. Wales*, 80, 220-3 (1947); *Chem. Abstr.*, 42, 1902 (1948).

²⁰² Wuyts and Lacourt, *Bull. soc. chim. Belg.*, 45, 445-53 (1936).

²⁰³ Sonn and Schmidt, *Ber.*, 57B, 1355-6 (1924).

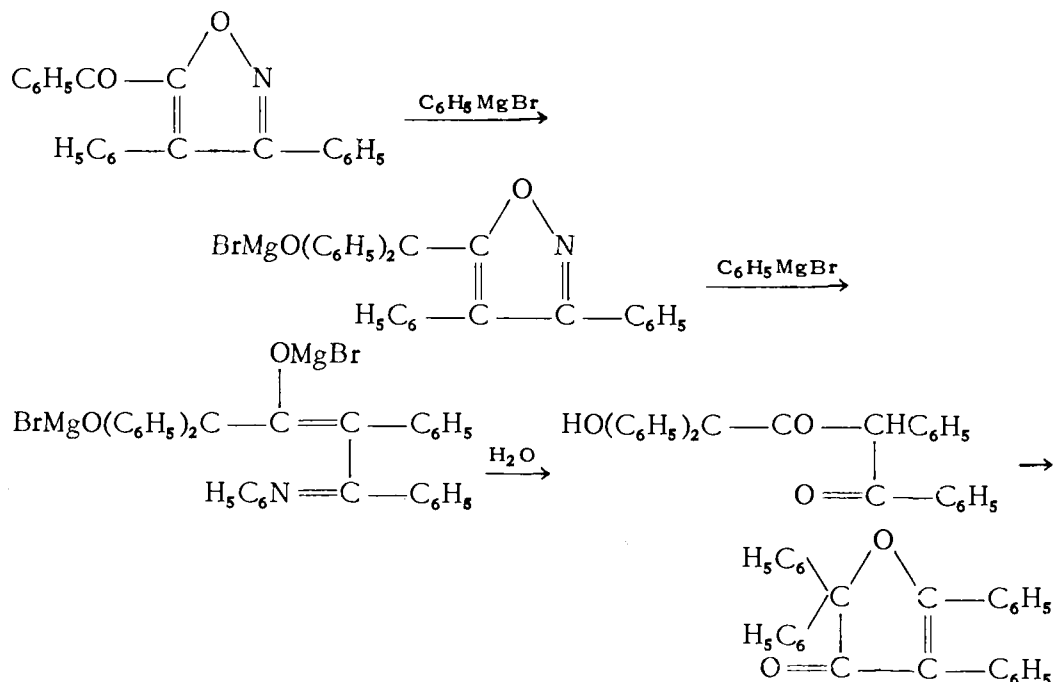
Similar reactions have been studied by Gilman and Morris,²⁰⁴ who prepared benzenesulfinanilide (80 percent yield), *p*-toluenesulfinanilide, and phenylmethanesulfinanilide (61.6 percent). The derivatives prepared with *n*-butylmagnesium bromide and cyclohexylmagnesium bromide are susceptible to hydrolysis and spontaneous oxidation, and were recovered as the sulfonates in 80 and 75 percent yields respectively.

Meyer and Näbe²⁰⁵ treated cyanuric bromide with ethylmagnesium bromide and obtained a product which upon hydrolysis with hydrochloric acid, yielded propionic acid.



From cyanuric chloride and phenylmagnesium bromide Ostragovich²⁰⁶ obtained a mixture of the dichloromonophenyl- and monochlorodiphenyl-1,3,5-triazines.

According to Kohler²⁰⁷ 3,4-diphenyl-5-benzoylisoxazole reacts as a ketone with one equivalent of Grignard reagent. With excess reagent, however, the reaction proceeds farther; the product isolated is a furanone.



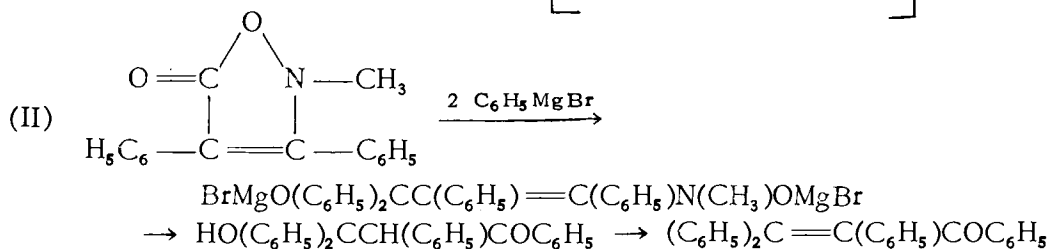
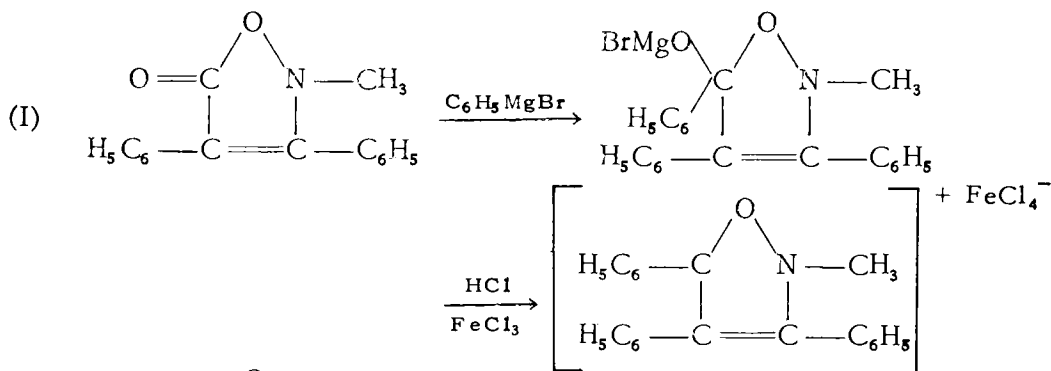
²⁰⁴ Gilman and Morris, *J. Am. Chem. Soc.*, 48, 2399-404 (1926).

²⁰⁵ Meyer and Näbe, *J. prakt. Chem.*, [2], 82, 521-38 (1910).

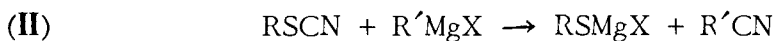
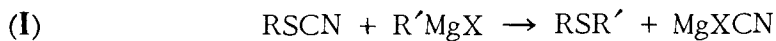
²⁰⁶ Ostragovich, *Chem.-Ztg.*, 36, 738-9 (1912); *Chem. Zentr.*, 1912, II, 607.

²⁰⁷ Kohler, (a) *J. Am. Chem. Soc.*, 46, 1733-47 (1924); (b) 47, 3030-6 (1925).

2-Methyl-3,4-diphenyl- Δ^3 -isoxazolinone forms two products with phenylmagnesium bromide. Kohler and Blatt²⁰⁸ described the reactions involved as follows:



According to Adams *et al.*²⁰⁹ alkyl thiocyanates appear to react with Grignard reagents in a manner reminiscent of that of cyanogen bromide (*q.v.*, Chapter X).



When isobutyl thiocyanate and ethylmagnesium bromide are the reactants, reaction **II** predominates when the normal order of addition is employed, and reaction **I** when the order of addition is reversed.

Evidence for the formation of $\text{R}'\text{CN}$ is seen in the products of the reactions of phenylmagnesium bromide with isobutyl thiocyanate and with benzyl thiocyanate, among which benzophenone anil and benzophenone are prominent.

Other reactions reported are those of ethylmagnesium bromide with isobutyl, *n*-heptyl, and benzyl isocyanates, and that of isobutylmagnesium bromide with benzyl isocyanate.

²⁰⁸ Kohler and Blatt, *J. Am. Chem. Soc.*, 50, 1217-26 (1928).

²⁰⁹ Adams, Bramlet, and Tendick, *J. Am. Chem. Soc.*, 42, 2369-74 (1920).

CHAPTER XX

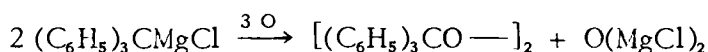
Reactions of Grignard Reagents with Oxygen, Sulfur, Selenium, and Tellurium

OXYGEN

The oxygen-oxidation of aromatic Grignard reagents was first reported by Bodroux,¹ who thereby obtained several phenols in 5-10 percent yields. In a subsequent paper² somewhat higher yields (10-22 percent) were claimed for these and several naphthols.

Bouveault³ isolated about 20 percent of cyclohexanol from the cyclohexanecarboxylic acid obtained by the carbonation of cyclohexylmagnesium chloride, and correctly attributed the byproduct to an oxidation reaction analogous to that reported by Bodroux (arising from oxygen contamination of the carbon dioxide used). Having only a limited supply of cyclohexyl chloride available, he checked his conclusion by oxidation of benzylmagnesium chloride, from which he obtained an 80 percent yield of benzyl alcohol. The oxidation of cyclohexylmagnesium chloride to form cyclohexanol was later confirmed by Sabatier and Mailhe.⁴ Similar oxidation of phenethylmagnesium bromide to form phenethyl alcohol in 60 percent yield was reported by Grignard.⁵

Schmidlin⁶ observed the atmospheric oxidation of triphenylmethyl Grignard reagents, which he formulated as follows:



although triphenylcarbinol was obtained upon hydrolysis of the reaction mixture. Schmidlin's report is contradicted by Bachmann and Cockerill,⁷ who maintain that the principal oxygenation product of triphenylmethylmagnesium bromide is the carbinolate.

Wuyts⁸ studied the oxidation of phenylmagnesium bromide in ethereal solution in some detail, and isolated from the reaction mixture: phenol, other unidentified phenolic substances, benzene, biphenyl, *p*-terphenyl,

¹ Bodroux, *Compt. rend.*, 136, 158-9 (1903); *Chem. Zentr.*, 1903, I, 508.

² Bodroux, *Bull. soc. chim.*, [3], 31, 33-6 (1904).

³ Bouveault, *Bull. soc. chim.*, [3], 29, 1051-4 (1903).

⁴ Sabatier and Mailhe, *Ann. chim.*, [8], 10, 527-71 (1907).

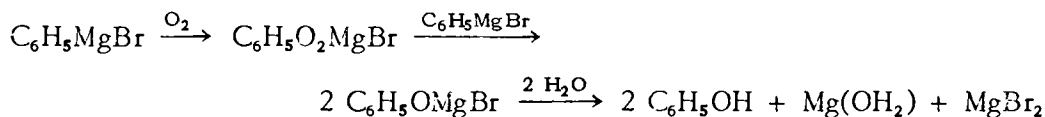
⁵ Grignard, *Compt. rend.*, 138, 1048-50 (1904); *J. Chem. Soc.*, 86, I, 494 (1904).

⁶ Schmidlin, *Ber.*, 39, 628-36, 4183-98 (1906); 41, 423-5 (1908).

⁷ Bachmann and Cockerill, *J. Am. Chem. Soc.*, 55, 2932-4 (1933).

⁸ Wuyts, *Compt. rend.*, 148, 930-1 (1909); *Chem. Zentr.*, 1909, I, 1855.

α -phenylethanol, and ethanol. He proposed that the formation of the phenolate takes place in two steps, of which the first is the peroxidation of the Grignard reagent.



The ethanol and α -phenylethanol were ascribed to a side-reaction of the Grignard peroxide with ethyl ether, yielding, with other products, ethanol and acetaldehyde. Wuyts showed that oxygenated ethereal phenylmagnesium bromide solutions give positive peroxide tests with hydroquinone, diphenylamine, and *p*-dimethylaminophenyl sulfide.

The effect of temperature on the yields of phenol obtainable by the oxidation of phenylmagnesium bromide was studied by Porter and Steele,⁹ who found that over the range from 0° to 32° the yield steadily decreased from 22.9 to 16.8 percent. Among the byproducts of the reaction they identified terphenyl, quinone, and 4,4'-dihydroxybiphenyl. According to them, biphenyl is a product solely of the Wurtz side-reaction in the preparation of the Grignard reagent, and does not increase in amount during the oxidation.

Ivanoff¹⁰ found that there is little difference in the yields of phenol obtainable by oxidation of phenylmagnesium bromide at -20° (28.8 percent) and at -55 to -50° (27.8 percent). Adopting -20° as the probable optimum temperature of operation, he investigated the oxidation of several arylmagnesium bromides, alone and in the presence of equimolecular quantities of alkylmagnesium halides. In all cases the yields of phenolic products obtainable by the oxidation of arylmagnesium bromides alone were nearly doubled in the presence of a molecular equivalent of alkylmagnesium halide. (Gilman¹¹ has made use of Ivanoff's method in the preparation of dibenzofuranols without discussion of its theoretical implications.) Ivanoff also showed that the increased yield of phenol obtainable by the oxidation of phenylmagnesium bromide in the presence of one equivalent of benzylmagnesium chloride (47.5 percent) is further enhanced when the oxidation is carried out in the presence of two equivalents of the alkyl reagent (53.3 percent).

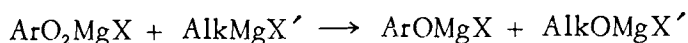
Strangely enough, Ivanoff (*loc. cit.*¹⁰) concluded that in the "mixed" reaction the alkyl Grignard reagent is first peroxidized, and the peroxide is then reduced by the aryl Grignard reagent. Wuyts,¹² however, offered the more probable interpretation that alkyl Grignard reagents are in general better reducing agents than aryl Grignard reagents, and hence effect more readily the second step of the postulated reaction sequence.

⁹ Porter and Steele, *J. Am. Chem. Soc.*, 42, 2650-4 (1920).

¹⁰ Ivanoff, *Bull. soc. chim.*, [4], 39, 47-55 (1926).

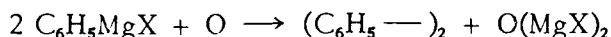
¹¹ Gilman, Bywater, and Parker, *J. Am. Chem. Soc.*, 57, 885-7 (1935); Gilman and Van Ess, *ibid.*, 61, 1365-71 (1939).

¹² Wuyts, *Bull. soc. chim. Belg.*, 36, 222-38 (1927).



This view would explain not only the enhanced yields of phenols obtainable by oxidation of aryl Grignard reagents in the presence of alkyl Grignard reagents but the relatively high yields of alcohols generally obtainable by oxidation of alkyl Grignard reagents as compared with the relatively poor yields of phenols obtainable by the oxidation of aryl Grignard reagents (see Table XX-II).

Kharasch and Reynolds¹³ have extended Ivanoff's study on the oxidation of aryl-alkyl Grignard reagent mixtures, and have reached conclusions similar to those of Wuyts. They have further shown that the addition of cobaltous chloride (CoCl_2) to the reaction system has relatively little effect on the course of the reaction in the oxidation of an alkyl Grignard reagent, but that in the oxidation of an aryl Grignard reagent it materially decreases the yield of phenolic product and increases the yield of coupling product (*e.g.*, biphenyl from phenylmagnesium bromide). Incidentally, it would appear that Porter and Steele (*loc. cit.*⁹) are probably wrong in their contention that no biphenyl is formed during the oxidation of phenylmagnesium bromide. Under experimental conditions commonly employed the amount of Wurtz byproduct arising from the preparation of the Grignard reagent should not exceed 10–12 percent; with reasonable care it can undoubtedly be held to considerably less. Significantly larger amounts of biphenyl have been isolated from phenylmagnesium bromide oxidation reaction mixtures by Wuyts (*loc. cit.*⁸) (15.4–20.6 percent), by Gilman and Wood¹⁴ (18 percent), and by Kharasch and Reynolds (*loc. cit.*¹³) (28 percent). Wuyts believed that biphenyl is formed by the reaction:



but it is at least equally probable that it results in other ways from the decomposition, or side-reaction with the solvent, of the peroxidized Grignard reagent.

Further direct experimental evidence regarding the first step of the oxygen-oxidation of Grignard reagents has been supplied by Walling and Buckler^{14,15}, who, by operating at low temperature (-71°), succeeded in preparing several alkyl hydroperoxides from the corresponding Grignard reagents. Their data are summarized in Table XX-I.

Concerning the mechanism of the reaction, the hypothesis that appears to accord best with the known facts may be outlined as follows. (1) The formation of alcoholates or phenolates by the oxygen-oxidation of Grignard reagents takes place, as suggested by Wuyts, in two steps: (*a*) the peroxidation of the Grignard reagent, and (*b*) the reduction of the peroxide by a second molecule of Grignard reagent. (2) Whereas both aryl and alkyl Grignard reagents are readily peroxidized by molecular oxygen

¹³ Kharasch and Reynolds, *J. Am. Chem. Soc.*, 65, 501–4 (1943).

¹⁴ Gilman and Wood, *J. Am. Chem. Soc.*, 48, 806–10 (1926).

^{14,15} Walling and Buckler, *J. Am. Chem. Soc.*, 75, 4372–3 (1953).

TABLE XX-1

PREPARATION OF ALKYL HYDROPEROXIDES BY SLOW ADDITION OF ETHEREAL RMgX SOLUTION (50 ml.) TO O₂-SATURATED Et₂O (50 ml.)

RMgX (N)	Temp. (°C)	Time (min.)	Yield (%)
<i>t</i> -C ₄ H ₉ MgCl (0.53)	-7	80	27.9
<i>t</i> -C ₄ H ₉ MgCl (0.53)	-74	80	91.4
<i>t</i> -C ₄ H ₉ MgCl (1.62)	-65	40	34.4
<i>t</i> -C ₄ H ₉ MgCl (1.62)	-71	120	78.4
<i>t</i> -C ₄ H ₉ MgCl (1.74)	-69	70	45.9
<i>t</i> -C ₄ H ₉ MgCl (0.56)	-71	40	85.7
C ₂ H ₅ MgCl (0.48)	-71	40	57.0
C ₂ H ₅ MgBr (0.54)	-71	40	28.2
<i>t</i> -C ₅ H ₁₁ MgCl (0.35)	-71	40	91.9
(CH ₂) ₅ CHMgCl (0.52)	-71	40	66.2
(CH ₂) ₅ CHMgBr (0.69)	-71	40	30.0
C ₆ H ₅ CH ₂ MgCl (0.50)	-71	40	30.0
CH ₃ (<i>n</i> -C ₆ H ₁₃)CHMgCl (0.50)	-71	40	91.4

in the first step of the reaction, alkyl reagents are greatly superior to aryl reagents as reducing agents in the second step of the reaction. (3) In the absence of sufficiently effective Grignard reducing agents, the aryl peroxides react with ethyl ether or decompose or both. (4) Temperatures as low as -20° inhibit the reaction of aryl peroxides with ethyl ether or their decomposition or both, but little or no advantage accrues to operation at still lower temperatures.

Insofar as there is loss of intermediate peroxide by reaction with the solvent, it should be possible to effect improvement in the yield of phenolic product by operation in solvents less susceptible to peroxide attack than ethyl ether. Ivanoff (*loc. cit.*¹⁰), operating at -20° has reported an average yield of 34.8 percent of phenol in benzene (as compared with an average yield of 28.8 percent in ethyl ether). Gilman and Wood (*loc. cit.*¹⁴) have reported a 45 percent yield of phenol in phenetole (as compared with a 29 percent yield in ethyl ether at -5°).

When employed as a preparative method, the oxidation of most alkylmagnesium bromides and chlorides with dry, carbon dioxide-free air or oxygen may be expected to give good to excellent yields of the corresponding alcohols. The best chance of obtaining fair to good yields of phenolic products by the analogous oxidation of arylmagnesium bromides or chlorides is insured by operating in relatively inert solvents (*e.g.*, benzene, toluene, anisole, phenetole) at reasonably low temperatures (*ca.* 0°) in the presence of one and a half to two molecular equivalents of an alkylmagnesium chloride or bromide. The use of iodides is to be avoided, for Meisenheimer and Schlichenmayer¹⁵ have shown that considerable quantities of iodides (corresponding to the desired alcohols or phenols) are formed in such reactions.

¹⁵Meisenheimer and Schlichenmayer, *Ber.*, 61B, 2029-43 (1928); *Chem. Abstr.*, 14, 172 (1920); *Atti accad. Lincei*, 27,II, 300-4 (1918); *J. Chem. Soc.*, 116,I, 134; *Chem. Abstr.*, 13, 3324 (1919).

Among the Grignard reagents which do not yield hydroxy compounds upon oxygenation are the pyrrolmagnesium halides, which form "pyrrole blacks."¹⁶ This, however, is scarcely surprising in view of the facility with which pyrrole itself undergoes "autoxidation."

TABLE XX-II
THE OXYGEN-OXIDATION OF GRIGNARD REAGENTS

<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
CH₃		
CH ₃ MgI	CH ₃ I; CH ₃ OH	34
C₂		
(≡CMgBr) ₂	No isolable product	20
C₂H		
HC≡CMgBr	CH ₃ CO ₂ H (23%)	21
C₂H₅		
C ₂ H ₅ MgBr	C ₂ H ₅ OH (88.5%)	52
C ₂ H ₅ MgI	C ₂ H ₅ I; C ₂ H ₅ OH	34
C₃H₄F₃		
F ₃ CCH ₂ CH ₂ MgCl (0.8 mole C ₃ H ₄ ClF ₃)	F ₃ CCH ₂ CH ₂ OH (36 g.)	33
C₄H₄N		
Pyrrol-MgI	"Pyrrole black"	1
C₄H₉		
<i>i</i> -C ₄ H ₉ MgBr	<i>i</i> -C ₄ H ₉ OH (74%)	50
<i>t</i> -C ₄ H ₉ MgCl	<i>t</i> -C ₄ H ₉ OH (80%)	50
C₆H₅		
C ₆ H ₅ MgBr	C ₆ H ₅ OH (5-10%; 18%)	6,7
C ₆ H ₅ MgBr	C ₆ H ₆ (10.6-23.1%); CH ₃ (C ₆ H ₅)CHOH (11.8-20.3%); (C ₆ H ₅) ₂ O; (C ₆ H ₅ —) ₂ (15.4-20.6%); (C ₆ H ₅) ₂ C ₆ H ₄ ; C ₆ H ₅ OH (27.8%); C ₂ H ₅ OH	52,49
C ₆ H ₅ MgBr	C ₆ H ₅ OH (22.9-16.8% at 0-32°); (C ₆ H ₅) ₂ C ₆ H ₄ ; (4-HOC ₆ H ₄ —) ₂ ; quinone	36,17
C ₆ H ₅ MgBr	C ₆ H ₅ OH (av'ge 28.8% at -20°; 27.8% at -55 to -50°)	24
C ₆ H ₅ MgBr + 1 equiv. C ₂ H ₅ MgBr	C ₆ H ₅ OH (av'ge 38.3% at -20°)	24
C ₆ H ₅ MgBr + 1 equiv. <i>n</i> -C ₃ H ₇ MgBr	C ₆ H ₅ OH (av'ge 41.6% at -20°)	24
C ₆ H ₅ MgBr + 1 equiv. <i>i</i> -C ₃ H ₇ MgBr	C ₆ H ₅ OH (av'ge 46.7% at -20°; av'ge 42.7% at 0° and at room temp.)	24
C ₆ H ₅ MgBr + 1 equiv. C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ OH (av'ge 47.5% at -20°)	24

¹⁶Angeli and Pieroni, *Gazz. chim. ital.*, 49,1, 154-8 (1919).

TABLE XX-II (Continued)

<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₅ (cont.)		
C ₆ H ₅ MgBr + 2 equiv. C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ OH (av'ge 53.3% at -20°)	24
C ₆ H ₅ MgBr	C ₆ H ₅ OH (28%)	27
C ₆ H ₅ MgBr + 1.1 equiv. <i>i</i> -C ₃ H ₇ MgBr	C ₆ H ₅ OH (43%)	27
C ₆ H ₅ MgBr + 1.5 equiv. <i>i</i> -C ₃ H ₇ MgBr	C ₆ H ₅ OH (64%)	27
C ₆ H ₅ MgBr + 1.5 equiv. <i>n</i> -C ₄ H ₉ MgBr	C ₆ H ₅ OH (47%)	27
C ₆ H ₅ MgBr + 1.2 equiv. (CH ₂) ₅ CHMgBr	C ₆ H ₅ OH (74%)	27
C ₆ H ₅ MgI	C ₆ H ₅ I; C ₆ H ₅ OH; CH ₃ (C ₆ H ₅)CHOH; C ₆ H ₆	34
C₆H₁₁		
(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CHOH (80.7%); [(CH ₂) ₅ CH] ₂ O	49,39,4
C₆H₁₃		
CH ₃ (<i>i</i> -C ₄ H ₉)CHMgCl	CH ₃ (<i>i</i> -C ₄ H ₉)CHOH (62%)	48
<i>n</i> -C ₃ H ₇ (CH ₃) ₂ CMgCl	<i>n</i> -C ₃ H ₇ (CH ₃) ₂ COH (48%); C ₆ H ₁₂	48
C₇H₇		
C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ OH (80%)	9
2-CH ₃ C ₆ H ₄ MgBr	2-CH ₃ C ₆ H ₄ OH (5-10%; 20%)	6,7
2-CH ₃ C ₆ H ₄ MgBr	2-CH ₃ C ₆ H ₄ OH (27.2% at -20°)	24
2-CH ₃ C ₆ H ₄ MgBr + 1 equiv. C ₆ H ₅ CH ₂ MgCl	2-CH ₃ C ₆ H ₄ OH (av'ge 40.8% at -20°)	24
3-CH ₃ C ₆ H ₄ MgBr	3-CH ₃ C ₆ H ₄ OH (25.1% at -20°)	24
4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ OH (5-10%; 15%)	6,7
4-CH ₃ C ₆ H ₄ Mg	4-CH ₃ C ₆ H ₄ OH (15.3%); (4-CH ₃ C ₆ H ₄ -) ₂ (16.0%); CH ₃ C ₆ H ₅ (11.0%); CH ₃ (4-CH ₃ C ₆ H ₄)CHOH (11.0%)	17
4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ OH (28.5% at -20°)	24
4-CH ₃ C ₆ H ₄ MgBr + 1 equiv. C ₆ H ₅ CH ₂ MgCl	4-CH ₃ C ₆ H ₄ OH (av'ge 54.1% at -20°)	24
C₆H₉		
<i>n</i> -C ₄ H ₉ C≡CMgBr	"Relatively inert" (-31°, 8 hrs.)	28
C₇H₇O		
4-CH ₃ OC ₆ H ₄ MgBr	4-CH ₃ OC ₆ H ₄ MgBr (5-10%; 12%)	6,7
C₇H₁₅		
<i>i</i> -C ₃ H ₇ CH(CH ₃)CH ₂ CH ₂ MgCl (0.11 mole C ₇ H ₁₅ Cl)	<i>i</i> -C ₃ H ₇ CH(CH ₃)CH ₂ CH ₂ OH (8 g.)	40
CH ₃ (<i>i</i> -C ₅ H ₁₁)CHMgCl	CH ₃ (<i>i</i> -C ₅ H ₁₁)CHOH (60%)	48
CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CHMgCl	CH ₃ (<i>t</i> -C ₄ H ₉ CH ₂)CHOH (65.4%)	35,48
<i>n</i> -C ₄ H ₉ (CH ₃) ₂ CMgCl	<i>n</i> -C ₄ H ₉ (CH ₃) ₂ COH (42%); C ₇ H ₁₄	48
<i>i</i> -C ₄ H ₉ (CH ₃) ₂ CMgCl	<i>i</i> -C ₄ H ₉ (CH ₃) ₂ COH (32%); C ₇ H ₁₄	48
<i>t</i> -C ₄ H ₉ (CH ₃) ₂ CMgCl	<i>t</i> -C ₄ H ₉ (CH ₃) ₂ COH	46
CH ₃ (C ₂ H ₅)(<i>i</i> -C ₃ H ₇)CMgCl	CH ₃ (C ₂ H ₅)(<i>i</i> -C ₃ H ₇)COH (31.7%)	35

TABLE XX-II (Continued)

<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₅		
C ₆ H ₅ C≡CMgBr	C ₆ H ₅ CH=CO	20
C₈H₆NaO₂		
C ₆ H ₅ CH(CO ₂ Na)MgX	C ₆ H ₅ CH(OH)CO ₂ H (38%); [HO ₂ C(C ₆ H ₅)CH—] ₂ (8%)	25
C₈H₉		
C ₆ H ₅ CH ₂ CH ₂ MgBr	C ₆ H ₅ CH ₂ CH ₂ OH (60%)	19
C₈H₉O		
4-C ₂ H ₅ OC ₆ H ₄ MgBr	4-C ₂ H ₅ OC ₆ H ₄ OH (5-10%)	6,7
C₈H₁₂N		
Cryptopyrryl-MgBr	(3,5-Dimethyl-4-ethyl-2-pyrryl)(3,5-dimethyl-4-ethyl-2-pyrryl-idene)methane; C ₁₆ H ₂₄ ON ₂ (8-10%)	13
C₈H₁₇		
<i>n</i> -C ₈ H ₁₇ MgBr	<i>n</i> -C ₈ H ₁₇ OH (80%)	18
<i>t</i> -C ₄ H ₉ (CH ₃) ₂ CCH ₂ MgCl (36 g. C ₈ H ₁₇ Cl)	<i>t</i> -C ₄ H ₉ (CH ₃) ₂ CCH ₂ OH (17 g., 53%)	51
C₉H₉		
4-H ₂ C=CHCH ₂ C ₆ H ₄ MgBr (40 g. C ₉ H ₉ Br)	4-H ₂ C=CHCH ₂ C ₆ H ₄ OH (5 g.)	37
4-CH ₃ CH=CHC ₆ H ₄ MgBr	4-CH ₃ CH=CHC ₆ H ₄ OH (30%)	37
C₉H₁₁		
4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ MgCl	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ OH (71-80% on basis of G. r. consumed)	5
4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ MgBr	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ OH (25 g., 18%); <i>i</i> -C ₃ H ₇ C ₆ H ₅ (66 g.)	4
C₁₀H₆Br		
4-BrC ₁₀ H ₆ -1-MgBr	4-BrC ₁₀ H ₆ -1-OH (22%)	7
5-BrC ₁₀ H ₆ -2-MgBr	5-BrC ₁₀ H ₆ -2-OH	12
C₁₀H₆Cl		
4-ClC ₁₀ H ₆ -1-MgBr	4-ClC ₁₀ H ₆ -1-OH (21%)	7
C₁₀H₇		
1-C ₁₀ H ₇ MgBr	1-C ₁₀ H ₇ OH (12%)	7
1-C ₁₀ H ₇ MgBr + 1.7 equiv. <i>i</i> -C ₃ H ₇ MgBr	1-C ₁₀ H ₇ OH (70%)	27
C₁₀H₁₇		
C ₁₀ H ₁₇ MgCl*	Borneol and isoborneol in approx. 1:1 ratio	38,3,22,23

* From pinene hydrochloride, bornyl chloride, or isobornyl chloride.

TABLE XX-II (Continued)

<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₀H₁₇ (cont.)		
C ₁₀ H ₁₇ MgCl [†]	<i>trans</i> -2-Decalol, m. 75° (5/6 of product); <i>trans</i> -2-decalol, m. 53° (1/6 of product)	11,10
C ₁₀ H ₁₇ MgCl [‡]	<i>cis</i> -2-Decalol, m. 19° (2/5 of product); <i>cis</i> -2-decalol, m. 105° (3/5 of product)	11
C ₁₀ H ₁₇ MgCl [§]	2-Decalol, m. 75°	10
C ₁₀ H ₁₇ MgCl [¶]	<i>cis</i> -2-Decalol, m. 19°	10
C₁₁H₉O		
6-CH ₃ OC ₁₀ H ₆ -2-MgBr (118.5 g. C ₁₁ H ₉ BrO) + <i>i</i> -C ₃ H ₇ MgBr (123.0 g. C ₃ H ₇ Br)	6-CH ₃ OC ₁₀ H ₆ -2-OH (40-42%)	14
C₁₁H₁₅O		
C ₆ H ₅ O(CH ₂) ₅ MgI	C ₆ H ₅ O(CH ₂) ₅ OH	47
C₁₂H₇O		
1-Dibenzofuryl-MgBr	1-Dibenzofuranol	26
2-Dibenzofuryl-MgBr (36.5 g. C ₁₂ H ₇ BrO) + <i>n</i> -C ₄ H ₉ MgBr (19.1 g. C ₄ H ₉ Br)	2-Dibenzofuranol (36.7%, crude)	15
C₁₂H₉		
4-C ₆ H ₅ C ₆ H ₄ MgX	4-C ₆ H ₅ C ₆ H ₄ OH	44
C₁₂H₉O		
4-C ₆ H ₅ OC ₆ H ₄ MgCl	4-C ₆ H ₅ OC ₆ H ₄ OH	29
C₁₃H₉O₂		
2-Methoxy-3-dibenzo- furyl-MgBr (0.15 mole C ₁₃ H ₉ BrO ₂) + <i>n</i> -C ₄ H ₉ MgBr (0.15 mole C ₄ H ₉ Br)	2-Methoxy-3-dibenzofuranol (71%)	16
C₁₃H₁₇		
4-(CH ₂) ₅ CHC ₆ H ₄ CH ₂ MgCl	4-(CH ₂) ₅ CHC ₆ H ₄ CH ₂ OH (34%)	8
C₁₄H₉		
9-Phenanthryl-MgBr	9-Phenanthrol (23%)	2

[†] From chlorinated *trans*-decalin.

[‡] From chlorinated *cis*-decalin.

[§] From *trans*-2-chlorodecalin.

[¶] From chlorinated *cis*- β -decalin.

TABLE XX-II (Continued)

<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₄H₉O		
2,2,5,7,8-Pentamethyl-6-chromanyl-MgBr (4 g. C ₁₄ H ₉ BrO)	2,2,5,7,8-Pentamethyl-6-chromanol (250 mg.)	45
C₁₆H₃₃		
<i>n</i> -C ₁₆ H ₃₃ MgBr	<i>n</i> -C ₁₆ H ₃₃ OH (59%)	18
C₁₉H₁₅		
(C ₆ H ₅) ₃ CMgCl	(C ₆ H ₅) ₃ COH	41,42,43
C₂₇H₄₅		
Cholesteryl-MgCl	<i>epi</i> -Cholesterol and cholesterol in approx. 1:1 ratio	32,31,30

REFERENCES FOR TABLE XX-II

- (1) Angeli and Pieroni, *Gazz. chim. ital.*, 49,1, 154-8 (1919); *Chem. Abstr.*, 14, 172 (1920); *Atti accad. Lincei*, 27,II, 300-4 (1918); *J. Chem. Soc.*, 116,1, 134; *Chem. Abstr.*, 13, 3324 (1919).
- (2) Bachmann, *J. Am. Chem. Soc.*, 56, 1363-7 (1934).
- (3) Barbier and Grignard, *Bull. soc. chim.*, [3], 31, 840 (1904).
- (4) Bert, *Bull. soc. chim.*, [4], 37, 1397-410 (1925).
- (5) Bert, *Bull. soc. chim.*, [4], 37, 1577-91 (1925).
- (6) Bodroux, *Compt. rend.*, 136, 158-9 (1903); *Chem. Zentr.*, 1903,1, 508.
- (7) Bodroux, *Bull. soc. chim.*, [3], 31, 33-6 (1904).
- (8) Bodroux and Thomassin, *Bull. soc. chim.*, [5], 6, 1411-6 (1939).
- (9) Bouveault, *Bull. soc. chim.*, [3], 29, 1051-4 (1903).
- (10) Cauquil and Inamura, *Bull. soc. chim.*, [5], 7, 660-1 (1940).
- (11) Cauquil and Tsatsas, *Compt. rend.*, 218, 463-4 (1944); *Chem. Abstr.*, 39, 2501 (1945).
- (12) Fieser and Riegel, *J. Am. Chem. Soc.*, 59, 2561-5 (1937).
- (13) Fischer, Baumgartner, and Plötz, *Ann.*, 493, 1-19 (1932).
- (14) French and Sears, *J. Am. Chem. Soc.*, 70, 1279-80 (1948).
- (15) Gilman, Bywater, and Parker, *J. Am. Chem. Soc.*, 57, 885-7 (1935).
- (16) Gilman and Van Ess, *J. Am. Chem. Soc.*, 61, 1365-71 (1939).
- (17) Gilman and Wood, *J. Am. Chem. Soc.*, 48, 806-10 (1926).
- (18) Goebel and Marvel, *J. Am. Chem. Soc.*, 55, 1693-6 (1933).
- (19) Grignard, *Compt. rend.*, 138, 1048-50 (1904); *J. Chem. Soc.*, 86,1, 494 (1904); *Chem. Zentr.*, 1904,1, 1493.
- (20) Grignard and Lepayre, *Bull. soc. chim.*, [4], 43, 141-2 (1928).
- (21) Grignard and Lepayre, *Bull. soc. chim.*, [4], 43, 930-1 (1928).
- (22) Hesse, *Ber.*, 39, 1127-55 (1906).
- (23) Houben, *Ber.*, 39, 1700-2 (1906).
- (24) Ivanoff, *Bull. soc. chim.*, [4], 39, 47-55 (1926).
- (25) Ivanov and Spasov, *Arhiv. Hem. Farm.*, 8, 8-10 (1934); *Chem. Abstr.*, 28, 6711 (1934).
- (26) Jacoby, Hayes, and Van Ess, *Proc. Iowa Acad. Sci.*, 43, 204-5 (1936); *Chem. Abstr.*, 32, 4160 (1938).
- (27) Kharasch and Reynolds, *J. Am. Chem. Soc.*, 65, 501-4 (1943).
- (28) Kroeger and Nieuwland, *J. Am. Chem. Soc.*, 58, 1861-3 (1936).

- (29) Mailhe and Murat, *Bull. soc. chim.*, [4], 11, 228-32 (1912).
- (30) Marker, U. S. Patent 2,255,074, Sept. 9, 1941; *Chem. Abstr.*, 35, P8216 (1941).
- (31) Marker, Kamm, Oakwood, and Laucius, *J. Am. Chem. Soc.*, 58, 1948-50 (1936).
- (32) Marker, Oakwood, and Crooks, *J. Am. Chem. Soc.*, 58, 481-3 (1936).
- (33) McBee and Truchan, *J. Am. Chem. Soc.*, 70, 2910-1 (1948).
- (34) Meisenheimer and Schlichenmayer, *Ber.*, 61B, 2029-43 (1928).
- (35) Miller, *J. Am. Chem. Soc.*, 69, 1764-8 (1947).
- (36) Porter and Steele, *J. Am. Chem. Soc.*, 42, 2650-4 (1920).
- (37) Quelet, *Bull. soc. chim.*, [4], 45, 255-74 (1929).
- (38) Rivière, *Ann. chim.*, [12], 1, 157-231 (1946).
- (39) Sabatier and Mailhe, *Ann. chim.*, [8], 10, 527-74 (1907).
- (40) Schmerling, *J. Am. Chem. Soc.*, 67, 1438-41 (1945).
- (41) Schmidlin, *Ber.*, 39, 628-36 (1906).
- (42) Schmidlin, *Ber.*, 39, 4183-98 (1906).
- (43) Schmidlin, *Ber.*, 41, 423-5 (1908).
- (44) Schmidlin, *Ber.*, 45, 3171-82 (1912).
- (45) Smith, U. S. Patent 2,397,212, Jan. 7, 1943; *Chem. Abstr.*, 40, P3573 (1946).
- (46) Stevens and McCoubrey, *J. Am. Chem. Soc.*, 63, 2847-8 (1941).
- (47) von Braun, Deutsch, and Schmatloch, *Ber.*, 45, 1246-63 (1912).
- (48) Whitmore and Johnston, *J. Am. Chem. Soc.*, 60, 2265-7 (1938).
- (49) Wuyts, *Bull. soc. chim. Belg.*, 36, 222-38 (1927).
- (50) Whitmore and Lux, *J. Am. Chem. Soc.*, 54, 3448-54 (1932).
- (51) Whitmore, Marker, and Plambeck, *J. Am. Chem. Soc.*, 64, 1626-30 (1941).
- (52) Wuyts, *Compt. rend.*, 148, 930-1 (1909); *Chem. Zentr.*, 1909, I, 1855.

The implication that many preparative, and all investigative Grignard reactions should be protected from oxygen is obvious. Gilman *et al.*¹⁷ have repeatedly warned that oxidation losses during prolonged Grignard reagent refluxes are likely to be considerable, and Gilman and Zoellner¹⁸ caution against similar losses in carbonation reactions. Goebel and Marvel¹⁹ have pointed out that, at 0° or below, oxidation of exposed Grignard reagent solutions is very rapid because at such low temperatures ether vapor affords practically no protection of the solution.

CHEMILUMINESCENCE

Procedure for a lecture-demonstration of the chemiluminescent effect arising from the treatment of ethereal phenylmagnesium bromide with moist air was described by Heczko,²⁰ who, however, erroneously attributed the effect to moisture. Among others who have observed chemiluminescence accompanying the oxygenation of Grignard reagents are

¹⁷ Gilman, Beaber, and Myers, *J. Am. Chem. Soc.*, 47, 2047-52 (1925); Gilman and Wood, *ibid.*, 48, 806-10 (1926); Gilman and St. John, *Bull. soc. chim.*, [4], 45, 1091-5 (1929); Gilman and Hewlett, *Rec. trav. chim.*, 48, 1124-8 (1929).

¹⁸ Gilman and Zoellner, *J. Am. Chem. Soc.*, 53, 1945-8 (1931).

¹⁹ Goebel and Marvel, *J. Am. Chem. Soc.*, 55, 1693-6 (1933).

²⁰ Heczko, *Chem.-Ztg.*, 35, 199-200 (1911); *Chem. Zentr.*, 1911, I, 1032; *Chem. Abstr.*, 5, 1706 (1911).

Schmidlin,²¹ Späth,²² and Bachmann.²³ The effect has been studied by Möller,²⁴ by Lifschitz,²⁵ and by Evans, Dufford, and co-workers.²⁶

Despite some apparently conflicting reports the following summary may be accepted as probably factual. (1) The intensity and apparent color of the chemiluminescence vary with the individual Grignard reagent and with the concentration of the solution. (2) In general the aryl Grignard reagents are more intensely luminescent than the alkyl reagents. (3) The maximum effect for aryl reagents is observable at concentrations approximating one molar; for alkyl reagents at higher dilutions (*ca.* one-eighth molar). (4) In general the aryl organomagnesium chlorides emit light of greatest intensity and longest wave-lengths, the iodides of least intensity and shortest wavelengths. (5) Although the intensity and apparent color of the luminescence vary with the organic radical of the Grignard reagent, there is no readily discernible simple relationship between structure and nature of the luminescent effect; molecular weight is not the controlling factor. (6) The presence of ether is not essential; the effect is observable in essentially ether-free solutions. (7) Temperature has little effect on the intensity or apparent color of the luminescence. (8) In general the rate of the oxidation reaction does not determine the intensity or color of the luminescence; for a given Grignard reagent the intensity is higher at higher oxidation rates. (9) The intensity and color of the luminescence are neither directly nor inversely relatable to the heat of the reaction.

On the whole, it would appear that no chemically significant generalizations may be based upon the existent data.

SULFUR

It was found by Wuyts and Cosyns²⁷ that sulfur (flowers) reacts vigorously upon gradual addition to an ethereal Grignard reagent. The products recovered upon hydrolysis were the thiols, the disulfides, and, in the case of phenylmagnesium bromide, the sulfide.

²¹ Schmidlin, *Ber.*, 45, 3171-82 (1912).

²² Späth, *Monatsh.*, 36, 4-12 (1915).

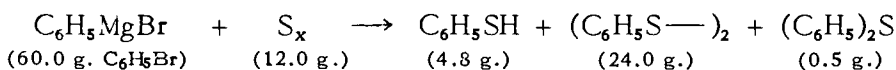
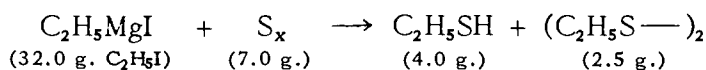
²³ Bachmann, *J. Am. Chem. Soc.*, 56, 1363-7 (1934).

²⁴ Möller, *Arch. Pharm. Chim.*, 21, 449 (1914); *Chem. Abstr.*, 9, 623 (1915).

²⁵ Lifschitz, *Helv. Chim. Acta*, 1, 472-4 (1918); Lifschitz and Kalberer, *Z. physik. Chem.*, 102, 393-45 (1922).

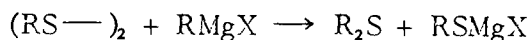
²⁶ Evans and Dufford, *J. Am. Chem. Soc.*, 45, 278-85 (1923); Dufford, Calvert, and Nightingale, *ibid.*, 45, 2058-72 (1923); 47, 95-102 (1925); Evans and Diepenhorst, *ibid.*, 48, 715-23 (1926); Dufford, Nightingale, and Gaddum, *ibid.*, 49, 858-64 (1927); Dufford, *ibid.*, 50, 1822-4 (1928); Dufford, Nightingale, and Calvert, *J. Optical Soc. Am.*, 9, 405-9 (1924); *Chem. Abstr.*, 19, 608 (1925); *Phys. Rev.*, [2], 21, 203-4 (1923); Thomas and Dufford, *J. Optical Soc. Am.*, 23, 251-5 (1933); *Chem. Abstr.*, 27, 4737 (1933).

²⁷ Wuyts and Cosyns, *Bull. soc. chim.*, [3], 29, 689-93 (1903).

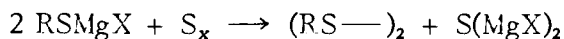


Taboury²⁸ treated some dozen arylmagnesium halides with octahedral sulfur which had been repeatedly crystallized from carbon disulfide and then pulverized, and obtained the corresponding thiols and disulfides.

Wuyts²⁹ attributed the phenyl sulfide detected in his study with Cosyns (*loc. cit.*²⁷) to a secondary reaction, and showed that phenylmagnesium bromide reacts with phenyl disulfide to form phenyl sulfide and bromomagnesium thiophenolate.



In a subsequent study³⁰ he showed that bromomagnesium thiophenolate reacts with sulfur to form phenyl disulfide and bromomagnesium sulfide.



The latter is the source of the hydrogen sulfide often liberated in the hydrolysis of sulfur reaction mixtures.

In his earlier paper²⁹ Wuyts suggested that the sulfur reaction might follow a course analogous to that of the oxygenation, but later³⁰ inclined to the opinion that the halomagnesium thiolate (RSMgX) is the initial reaction product. By avoiding, as far as possible, the presence of an excess of sulfur he was able to prepare thiophenol from phenylmagnesium bromide in 80 percent yield.

A good (70 percent) yield of thiol was obtained by Bachmann and Cockerill³¹ upon treatment of triphenylmethylmagnesium bromide with sulfur.

Mousseron *et al.*³² report (without specifying yields) the preparation of thiols from cyclopentylmethylmagnesium chloride, 3-methylcyclopentylmethylmagnesium chloride, 3-methylcyclohexylmagnesium chloride, 3-methylcyclohexylmethylmagnesium chloride, 2-cyclohexenyl-1-magnesium chloride, and 2-decalylmagnesium chloride.

Grignard and Lepayre³³ refluxed sulfur with an ethyl ethereal solution of ethynylidenemagnesium bromide $[(\equiv \text{CMgBr})_2]$ for fifty hours, and obtained a black powder of unknown constitution containing 66–72 percent sulfur.

²⁸ Taboury, *Compt. rend.*, 138, 982–3 (1904); *Chem. Zentr.*, 1904, I, 1413; *Bull. soc. chim.*, [3], 29, 761–5 (1903); *Ann. chim.*, [8], 15, 5–66 (1908).

²⁹ Wuyts, *Bull. soc. chim.*, [3], 35, 166 (1906).

³⁰ Wuyts, *Bull. soc. chim.*, [4], 5, 405–12 (1909).

³¹ Bachmann and Cockerill, *J. Am. Chem. Soc.*, 55, 2932–4 (1933).

³² Mousseron, Bousquet, and Marret, *Bull. soc. chim.*, [5], 15, 84–90 (1948).

³³ Grignard and Lepayre, *Bull. soc. chim.*, [4], 43, 930–1 (1928).

Sulfurization of pyrrolylmagnesium iodide like oxygenation, leads to the formation of "pyrrole blacks."^{34,35}

The β -indolylmagnesium bromides, upon treatment with sulfur, yield the sulfides (R_2S).^{34,35} Upon successive treatment with sulfur and an acyl halide, however, they yield the thiol esters ($RSOCR'$),^{34,35} together with disulfides $[(RS—)_2]$.³⁶

According to Oddo and Raffa (*loc. cit.*³⁶), the reaction of β -methyl- α -indolylmagnesium bromide with sulfur proceeds in a different way, probably through a dithio intermediate (RS_2MgBr). The product isolated is a trisulfide (R_2S_3).

SELENIUM

Taboury³⁷ treated seven arylmagnesium halides with selenium in a manner similar to that employed for sulfur, obtaining the selenols, the diselenides, and, in three cases, the selenides. By operating with a deficiency of selenium (0.8 equivalent), Wuyts³⁸ obtained selenophenol from phenylmagnesium bromide in 81.2 percent yield. According to Giua and Cherchi,³⁹ selenium, like oxygen and sulfur, yields "pyrrole black" with pyrrolylmagnesium bromide.

TELLURIUM

Giua and Cherchi (*loc. cit.*³⁹) treated phenylmagnesium bromide with tellurium and obtained tellurophenol and phenyl telluride. Pyrrolylmagnesium bromide, similarly treated, yielded "pyrrole black."

³⁴Giua and Cherchi, *Gazz. chim. ital.*, 50,1, 362-77 (1920); *Chem. Abstr.*, 15, 521 (1921).

³⁵Oddo and Mingoia, *Gazz. chim. ital.*, 62, 299-317 (1932); *Chem. Abstr.*, 26, 4603 (1932).

³⁶Oddo and Raffa, *Gazz. chim. ital.*, 71, 242-53 (1941); *Chem. Abstr.*, 36, 2854 (1942).

³⁷Taboury, *Compt. rend.*, 138, 982-3 (1904); *Chem. Zentr.*, 1904,1, 1413; *Bull. soc. chim.*, [3], 29, 761-5 (1903); *Ann. chim.*, [8], 15, 5-66 (1908).

³⁸Wuyts, *Bull. soc. chim.*, [4], 5, 405-12 (1909).

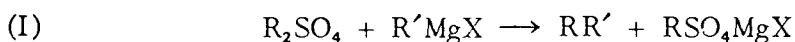
³⁹Giua and Cherchi, *Gazz. chim. ital.*, 50,1, 362-77 (1920); *Chem. Abstr.*, 15, 521 (1921).

CHAPTER XXI

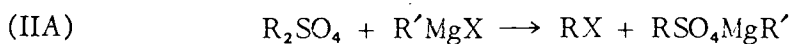
Reactions of Grignard Reagents with Miscellaneous Sulfur, Selenium, and Tellurium Compounds

ALKYL SULFATES

The idea of employing the reactions of alkyl sulfates (rather than of alkyl halides) with Grignard reagents for the preparation of hydrocarbons apparently occurred to Werner and Zilkens¹ and to Houben² nearly simultaneously.³ The reaction which they regarded as "normal," and which they reported, is described stoichiometrically as follows:



Upon more detailed investigation Suter and Gerhart⁴ found that there is in addition a reaction of the type:



When, for example, ethereal *n*-butylmagnesium bromide was treated with slightly more than one equivalent of ethyl sulfate the resultant solution contained nearly pure di-*n*-butylmagnesium, and there was an 86 percent yield of ethyl bromide (as estimated by bromide ion disappearance). The subject was sufficiently investigated to show that the mutual reactivities of various reactant pairs (with respect to reactions I and II) vary over a considerable range.

For obvious reasons it is recommended that, in general, a ratio of two moles of ester per mole of Grignard reagent be employed in preparative work. Suter and Gerhart (*loc. cit.*⁴) found that when phenylmagnesium bromide and *n*-butyl sulfate are combined in one-to-one ratio the yield of *n*-butylbenzene is about 16 percent, whereas doubling the proportion of ester increases the yield to 42 percent.

Bert⁵ has studied the reactions of phenylmagnesium bromide with methyl ethyl sulfate, ethyl *n*-propyl sulfate, and ethyl *n*-butyl sulfate, and reports that the hydrocarbon product in each case contains the smaller of the alkyl radicals originally present in the unsymmetrical ester. It ap-

¹ Werner and Zilkens, *Ber.*, 36, 2116-8 (1903).

² Houben, *Ber.*, 36, 3083-6 (1903).

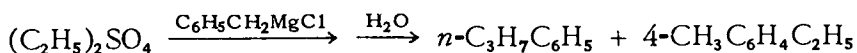
³ If interested in priority polemics see: Werner and Zilkens, *Ber.*, 36, 3618-9 (1903); Houben, *Ber.*, 37, 488-9 (1904).

⁴ Suter and Gerhart, *J. Am. Chem. Soc.*, 57, 107-9 (1935). See also: Cope, *ibid.*, 56, 1578-81 (1934).

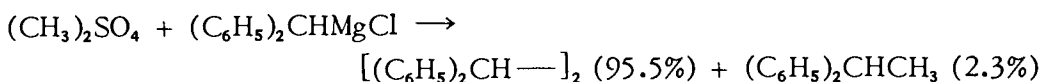
⁵ Bert, *Compt. rend.*, 178, 1182-4 (1924); *Chem. Zentr.*, 1924, II, 170.

pears probable that more extensive quantitative studies would lead to some qualification of this generalization.

Using especially prepared benzyl chloride, and employing the method of Gilman and Catlin,⁶ Burtle and Shriner⁷ treated benzylmagnesium chloride with ethyl sulfate, obtaining a product which, upon oxidation, yielded about 5 percent of terephthalic acid. This implies a rather unusual, though by no means unique, type of "allylic rearrangement" (*q.v.*, Chapter XVII), for most rearrangement products of benzylmagnesium halides are *o*-tolyl compounds.



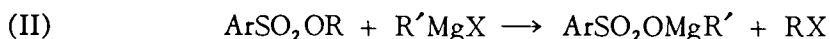
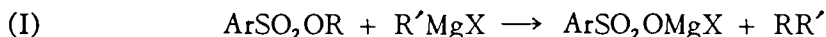
Gilman and Kirby⁸ report a reaction in which methyl sulfate apparently acts as a coupling reagent:



However, the tendency of benzhydryl chloride to yield Wurtz product during attempted Grignardization, as well as the tendency of the Grignard reagent toward homolytic dissociation, invites further study of this reaction with magnesium of high purity.

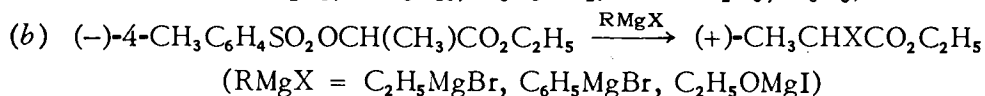
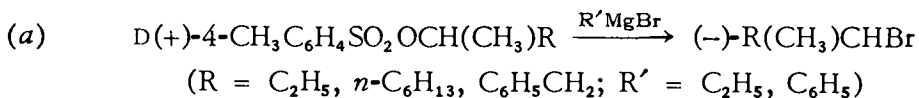
SULFONIC ESTERS

Like the alkyl sulfates, the alkyl esters of the aryl sulfonic acids react with Grignard reagents in two ways:⁹



Reaction I, first reported by Ferns and Lapworth,¹⁰ is usually regarded as "normal," and is most commonly employed for preparative purposes.

Kenyon *et al.*¹¹ have shown that when R is optically active reaction II takes place with retention of most of the optical activity, and presumably with inversion.



⁶ Gilman and Catlin, *Organic Syntheses*, Coll. Vol. I, 2nd ed., 471-3 (1941).

⁷ Burtle and Shriner, *J. Am. Chem. Soc.*, 69, 2059-60 (1947).

⁸ Gilman and Kirby, *J. Am. Chem. Soc.*, 48, 1733-6 (1926).

⁹ Suter and Gerhart, *J. Am. Chem. Soc.*, 57, 107-9 (1935).

¹⁰ Ferns and Lapworth, *Proc. Chem. Soc.*, 28, 18-9 (1912); *J. Chem. Soc.*, 101, 273-87 (1912).

¹¹ (a) Kenyon, Phillips, and Turley, *J. Chem. Soc.*, 127, 399-417 (1925); (b) Kenyon, Phillips and Pittman, *ibid.*, 1935, 1072-84.

TABLE XXI-I

REACTIONS OF GRIGNARD REAGENTS WITH SYMMETRICAL ALKYL SULFATES

<u>R₂SO₄</u>	<u>R'MgX</u>	<u>RR'</u>	<u>Ref.</u>
[(CH ₃) ₂ SO ₄]	(MgBr ₂)	[CH ₃ Br (93%)]	24
[(CH ₃) ₂ SO ₄]	(MgI ₂)	[CH ₃ I (97%)]	24
(CH ₃) ₂ SO ₄	5-Iodo-2-furyl-MgI	[2-Iodofuran (72%)]	23
(CH ₃) ₂ SO ₄	<i>t</i> -C ₄ H ₉ MgI	(CH ₃) ₄ C (75%)	3
(CH ₃) ₂ SO ₄	C ₆ H ₅ MgBr	CH ₃ C ₆ H ₅ (31%)	1
(CH ₃) ₂ SO ₄	C ₆ H ₅ MgBr	CH ₃ C ₆ H ₅ (41%)	2
2 (CH ₃) ₂ SO ₄	C ₆ H ₅ MgBr	CH ₃ C ₆ H ₅ (62%)	11
(CH ₃) ₂ SO ₄	C ₆ H ₅ MgBr	CH ₃ C ₆ H ₅ (37%)	24
(CH ₃) ₂ SO ₄	C ₆ H ₅ MgI	CH ₃ C ₆ H ₅ (22%)	24
(CH ₃) ₂ SO ₄	<i>n</i> -C ₄ H ₉ C ≡ CMgBr	<i>n</i> -C ₄ H ₉ C ≡ CCH ₃ (<i>ca.</i> 70%)	19
(CH ₃) ₂ SO ₄	3-F ₃ CC ₆ H ₄ MgBr	1-CH ₃ -3-F ₃ CC ₆ H ₄ (9%)	12
(CH ₃) ₂ SO ₄	C ₆ H ₅ CH ₂ MgCl	C ₂ H ₅ C ₆ H ₅ (21%)	2
(CH ₃) ₂ SO ₄	4-CH ₃ C ₆ H ₄ MgBr	1,4-(CH ₃) ₂ C ₆ H ₄ (74%)	1
(CH ₃) ₂ SO ₄	4-CH ₃ C ₆ H ₄ MgBr	1,4-(CH ₃) ₂ C ₆ H ₄ (68%)	2
(CH ₃) ₂ SO ₄	2,4-(CH ₃) ₂ C ₆ H ₃ MgBr	1,2,4-(CH ₃) ₃ C ₆ H ₃ (52%)	24
(CH ₃) ₂ SO ₄	2,4-(CH ₃) ₂ C ₆ H ₃ MgBr	1,2,4-(CH ₃) ₃ C ₆ H ₃ (50-60%)	22
(CH ₃) ₂ SO ₄	2,4-(CH ₃) ₂ C ₆ H ₃ MgI	1,2,4-(CH ₃) ₃ C ₆ H ₃ (29%)	24
2 (CH ₃) ₂ SO ₄	2,4-(CH ₃) ₂ C ₆ H ₃ MgI	1,2,4-(CH ₃) ₃ C ₆ H ₃ (37%)	9
(CH ₃) ₂ SO ₄	<i>n</i> -C ₆ H ₁₃ C ≡ CMgBr	<i>n</i> -C ₆ H ₁₃ C ≡ CCH ₃ (<i>ca.</i> 70%)	19
2 (CH ₃) ₂ SO ₄	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	1,2,4,6-(CH ₃) ₄ C ₆ H ₂ (52-60%)	8,18
(CH ₃) ₂ SO ₄	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	1,2,4,6-(CH ₃) ₄ C ₆ H ₂ (49%)	24
(CH ₃) ₂ SO ₄	1-C ₁₀ H ₇ CH ₂ MgCl	1-C ₁₀ H ₇ C ₂ H ₅ (55%)	21
(CH ₃) ₂ SO ₄	5-CH ₃ C ₁₀ H ₆ -1-MgBr	1,5-(CH ₃) ₂ C ₁₀ H ₆ (34%)	10
(CH ₃) ₂ SO ₄	8-CH ₃ C ₁₀ H ₆ -1-MgBr	1,8-(CH ₃) ₂ C ₁₀ H ₆ (36%)	10
(CH ₃) ₂ SO ₄	2,7-(CH ₃) ₂ C ₁₀ H ₅ -1-MgBr	1,2,7-(CH ₃) ₃ C ₁₀ H ₅	14
3 (CH ₃) ₂ SO ₄	2,6-(CH ₃) ₂ -4- <i>t</i> -C ₄ H ₉ C ₆ H ₂ MgBr	1,2,6-(CH ₃) ₃ -4- <i>t</i> -C ₄ H ₉ C ₆ H ₂ (33%)	15
(CH ₃) ₂ SO ₄	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ (CH ₂) ₃ MgCl	1- <i>i</i> -C ₃ H ₇ -4- <i>n</i> -C ₄ H ₉ C ₆ H ₄	16
(CH ₃) ₂ SO ₄	(C ₆ H ₅) ₂ CHMgCl	(C ₆ H ₅) ₂ CHCH ₃ (2%)	7

TABLE XXI-I (Continued)

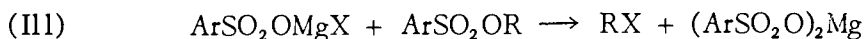
R_2SO_4	$R'MgX$	RR'	Ref.
$(C_2H_5)_2SO_4$	$H_2C=CHC \equiv CMgBr$	$H_2C=CHC \equiv CC_2H_5$ (ca. 70%)	19
$(C_2H_5)_2SO_4$	$n-C_4H_9MgBr$	$n-C_6H_{14}$ (69%)	4
$(C_2H_5)_2SO_4$	$4-BrC_6H_4MgBr$	$4-BrC_6H_4C_2H_5$ (45%)	4, 17
$(C_2H_5)_2SO_4$	C_6H_5MgBr	$C_6H_5C_2H_5$ (33%)	4
$(C_2H_5)_2SO_4$	$n-C_4H_9C \equiv CMgBr$	$n-C_4H_9C \equiv CC_2H_5$ (ca. 70%)	19
$(C_2H_5)_2SO_4$	$(CH_2)_5CHMgBr$	$(CH_2)_5CHC_2H_5$ (80%)	4
$2 (C_2H_5)_2SO_4$	$C_6H_5CH_2MgCl$	$C_6H_5-n-C_3H_7$ (70–75%)	6, 4
$2 (C_2H_5)_2SO_4$	$C_6H_5CH_2MgCl$	$C_6H_5-n-C_3H_7$ (chiefly); $4-C_2H_5C_6H_4CH_3$ (0.4–5.0%)	20
$(C_2H_5)_2SO_4$	$4-CH_3OC_6H_4MgBr$	$4-CH_3OC_6H_4C_2H_5$ (89%)	4
$(C_2H_5)_2SO_4$	$C_6H_5C \equiv CMgBr$	$C_6H_5C \equiv CC_2H_5$ (70%)	4
$(C_2H_5)_2SO_4$	$2-C_2H_5C_6H_4MgBr$	$1,2-(C_2H_5)_2C_6H_4$ (49%)	13
$(C_2H_5)_2SO_4$	$4-C_2H_5C_6H_4MgBr$	$1,4-(C_2H_5)_2C_6H_4$ (58%)	13
$(C_2H_5)_2SO_4$	$2,6-(CH_3)_2C_6H_3MgI$	$1,3-(CH_3)_2-2-C_2H_5C_6H_3$	18
$(C_2H_5)_2SO_4$	$n-C_6H_{13}C \equiv CMgBr$	$n-C_6H_{13}C \equiv CC_2H_5$ (ca. 70%)	19
$(C_2H_5)_2SO_4$	$1-C_{10}H_7MgBr$	$1-C_2H_5C_{10}H_7$ (71%)	4
$(C_2H_5)_2SO_4$	$4-i-C_3H_7C_6H_4(CH_2)_3MgCl$	$1-i-C_3H_7-4-n-C_5H_{11}C_6H_4$	16
$(i-C_3H_7)_2SO_4$	C_6H_5MgBr	$C_6H_5-i-C_3H_7$ (10%)	5
$(i-C_3H_7)_2SO_4$	$4-CH_3C_6H_4MgBr$	$1-CH_3-4-i-C_3H_7C_6H_4$ (10%)	5
$(i-C_3H_7)_2SO_4$	$4-i-C_3H_7C_6H_4(CH_2)_3MgCl$	$1-i-C_3H_7-4-i-C_6H_{13}C_6H_4$	16
$(n-C_4H_9)_2SO_4$	C_6H_5MgBr	$C_6H_5-n-C_4H_9$ (16%)	11
$2 (n-C_4H_9)_2SO_4$	C_6H_5MgBr	$C_6H_5-n-C_4H_9$ (42%)	11

REFERENCES FOR TABLE XXI-I

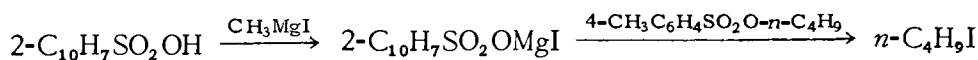
- (1) Werner and Zilkens, *Ber.*, 36, 2116-8 (1903).
- (2) Houben, *Ber.*, 36, 3083-6 (1903).
- (3) Ferrario and Fagetti, *Gazz. chim. ital.*, 38,II, 630-4 (1908); *Chem. Zentr.*, 1909,I, 463.
- (4) Gilman and Hoyle, *J. Am. Chem. Soc.*, 44, 2621-6 (1922).
- (5) Bert, *Compt. rend.*, 176, 840-7 (1923); *Chem. Abstr.*, 17, 1957 (1923).
- (6) Gilman and Catlin, *Organic Syntheses*, Coll. Vol. I, 2nd ed., 471-3 (1941); Gilman and Meyers, *Organic Syntheses*, 4, 59-61 (1925).
- (7) Gilman and Kirby, *J. Am. Chem. Soc.*, 48, 1733-6 (1926).
- (8) Smith, *Organic Syntheses*, Coll. Vol. II, 360-2 (1943); *Organic Syntheses*, 11, 66-9 (1931); Smith and MacDougall, *J. Am. Chem. Soc.*, 51, 3001-8 (1929).
- (9) Smith and Lund, *J. Am. Chem. Soc.*, 52, 4144-50 (1930).
- (10) Vesely and Stursa, *Collection Czechoslov. Chem. Comm.*, 3, 430-1 (1931); *Chem. Abstr.*, 25, 4877 (1931).
- (11) Suter and Gerhart, *J. Am. Chem. Soc.*, 57, 107-9 (1935).
- (12) Simons and Ramler, *J. Am. Chem. Soc.*, 65, 389-92 (1943).
- (13) Karabinos, Serijan, and Gibbons, *J. Am. Chem. Soc.*, 68, 2107-8 (1946).
- (14) Buu-Hoï and Lecocq, *J. Chem. Soc.*, 1946, 830-2.
- (15) Fuson, Mills, Klose, and Carpenter, *J. Org. Chem.*, 12, 587-95 (1947).
- (16) Bert, *Compt. rend.*, 186, 373-5 (1928); *Chem. Zentr.*, 1928,I, 1758.
- (17) Roy and Marvel, *J. Am. Chem. Soc.*, 57, 1311-4 (1935).
- (18) Birch, Dean, Fidler, and Lowry, *J. Am. Chem. Soc.*, 71, 1362-9 (1949).
- (19) Thorne, Hennion, and Nieuwland, *J. Am. Chem. Soc.*, 58, 796-7 (1936).
- (20) Burtle and Shriner, *J. Am. Chem. Soc.*, 69, 2059-60 (1947).
- (21) Gilman and Kirby, *J. Am. Chem. Soc.*, 51, 3475-8 (1929).
- (22) Maxwell and Adams, *J. Am. Chem. Soc.*, 52, 2959-72 (1930).
- (23) Gilman and Wright, *J. Am. Chem. Soc.*, 55, 3302-4 (1933).
- (24) Cope, *J. Am. Chem. Soc.*, 56, 1578-81 (1934).

Other than this nothing bearing on the mechanisms of the reactions has been established.

Gilman and Heck¹² have shown by direct experiment, and Rossander and Marvel¹³ by inference, that the sulfonates formed in reactions I and II are capable of further reaction with the sulfonic ester.



Gilman and Heck (*loc. cit.*¹²) confirmed equation III by carrying out the following reaction sequence:



Rossander and Marvel (*loc. cit.*¹³) confirmed, for several reactant pairs (see Table XXI-II), the implication of equation IV that a two-to-one ester-Grignard reagent ratio should result in higher RR' yields than a one-to-one ratio.

Data reported for reactions I and II, presumably including the contributions of reactions III and IV, are summarized in Table XXI-II.

¹² Gilman and Heck, *J. Am. Chem. Soc.*, 50, 2223-30 (1928).

¹³ Rossander and Marvel, *J. Am. Chem. Soc.*, 50, 1491-6 (1928).

TABLE XXI-II
REACTIONS OF GRIGNARD REAGENTS WITH ALKYL ESTERS
OF ARYL SULFONIC ACIDS

(α -C₄H₃S = 2-thienyl; C₇H₇ = *p*-tolyl)

ArSO ₂ OR	R'MgX	% RR'*	% RX*	Ref.
C ₆ H ₅ SO ₃ (CH ₂) ₂ Cl	R'MgX	+	...	13
C ₇ H ₇ SO ₃ CH ₃	C ₆ H ₅ MgBr	38	...	3
C ₇ H ₇ SO ₃ CH ₃	C ₆ H ₅ CH ₂ MgBr	41	...	3
C ₇ H ₇ SO ₃ CH ₃	C ₇ H ₇ MgBr	29	...	3
2 C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	(α -C ₄ H ₃ S)MgBr	71	...	14,16
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	<i>n</i> -C ₃ H ₇ C \equiv CMgBr	38	...	17
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	C ₆ H ₅ MgBr	36 [†]	...	2,6
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	C ₆ H ₅ CO ₂ MgBr	5	...	2
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	C ₆ H ₅ CH ₂ MgCl	59 [†]	...	2,6
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	2-CH ₃ C ₆ H ₄ MgBr	+ [†]	...	6
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	C ₇ H ₇ MgBr	+ [†]	...	6
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	C ₆ H ₅ C \equiv CMgBr	75	...	2
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	C ₆ H ₅ C \equiv CMgBr	46	86	18
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	C ₆ H ₅ CH=CHMgBr	0 [†]	0 [†]	12
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	C ₇ H ₇ CH ₂ MgCl	+ [†]	...	6
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	2,4-(CH ₃) ₂ C ₆ H ₃ MgBr	+ [†]	...	6
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	2,5-(CH ₃) ₂ C ₆ H ₃ MgBr	+ [†]	...	6
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	4- <i>i</i> -C ₃ H ₇ C ₆ H ₄ MgBr	+ [†]	...	6
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	2-CH ₃ -4- <i>i</i> -C ₃ H ₇ C ₆ H ₃ MgBr	+ [†]	...	6
C ₇ H ₇ SO ₃ (CH ₂) ₂ Cl	4- <i>n</i> -C ₇ H ₁₅ C ₆ H ₄ MgBr	30	...	15
C ₇ H ₇ SO ₃ C ₂ H ₅	C ₂ H ₅ MgI	...	32	5
C ₇ H ₇ SO ₃ C ₂ H ₅	C ₆ H ₅ MgBr	30	...	3,1
C ₇ H ₇ SO ₃ C ₂ H ₅	(CH ₂) ₅ CHMgBr	9	...	3
C ₇ H ₇ SO ₃ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl	38	...	3
C ₇ H ₇ SO ₃ C ₂ H ₅	C ₇ H ₇ MgBr	37	...	3
C ₇ H ₇ SO ₃ C ₂ H ₅	C ₆ H ₅ OC \equiv CMgBr	15	...	11
C ₇ H ₇ SO ₃ C ₂ H ₅	C ₆ H ₅ (CH ₂) ₃ MgCl	40	...	3
C ₇ H ₇ SO ₃ C ₂ H ₅	1-C ₁₀ H ₇ MgBr	19	...	3
C ₇ H ₇ SO ₃ C ₂ H ₅	<i>n</i> -C ₁₂ H ₂₅ MgBr	27	...	3
C ₇ H ₇ SO ₃ CH ₂ CH=CH ₂	C ₆ H ₅ CH ₂ MgCl	47	...	3
2 C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	C ₂ H ₅ MgBr	23	+	9
C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	(α -C ₄ H ₃ S)MgBr	61	...	16
C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	<i>n</i> -C ₄ H ₉ MgCl	...	+	9
C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	<i>n</i> -C ₄ H ₉ MgBr	...	+	9
C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	<i>n</i> -C ₄ H ₉ MgI	...	+	9
2-C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	C ₆ H ₅ MgBr	62	+	9
C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	(CH ₂) ₅ CHMgBr	14	+	9
2 C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	(CH ₂) ₅ CHMgBr	62	+	9

* Where a product is reported but the yield is not specifically stated, that fact is indicated by a plus sign in the appropriate column; where a product may have been present but apparently was not sought by the investigators cited, that fact is indicated by triple dots in the appropriate column.

[†] The yields of RR' product obtained by Bert (6) are reported as ranging from 30 to 80 percent and are said to have been "mostly high."

[‡] Khitrik (12) reports "no reaction."

TABLE XXI-II (Continued)

ArSO ₂ OR	R'MgX	% RR'*	% RX*	Ref.
2 C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	<i>n</i> -C ₆ H ₁₃ MgBr	52	+	9
C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	C ₆ H ₅ CH ₂ MgCl	42	+	9
2 C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	C ₆ H ₅ CH ₂ MgCl	50	+	9
C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	<i>n</i> -C ₇ H ₁₅ MgBr	11	+	9
2 C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	<i>n</i> -C ₇ H ₁₅ MgBr	50	+	9
C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	C ₆ H ₅ C≡CMgBr	75	...	18
C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	C ₆ H ₅ (CH ₂) ₄ MgCl	25	+	9
2 C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	C ₆ H ₅ (CH ₂) ₄ MgCl	44	+	9
2 C ₇ H ₇ SO ₃ (CH ₂) ₃ Cl	<i>n</i> -C ₁₂ H ₂₅ MgBr	30	+	9
2 C ₇ H ₇ SO ₃ - <i>n</i> -C ₃ H ₇	4-BrC ₆ H ₄ MgBr	43	...	7
C ₇ H ₇ SO ₃ - <i>n</i> -C ₃ H ₇	C ₆ H ₅ CH ₂ MgCl	36	...	3
C ₇ H ₇ SO ₃ - <i>n</i> -C ₄ H ₉	<i>n</i> -C ₃ H ₇ MgI	...	67	5
2 C ₇ H ₇ SO ₃ - <i>n</i> -C ₄ H ₉	4-BrC ₆ H ₄ MgBr	42	...	7
C ₇ H ₇ SO ₃ - <i>n</i> -C ₄ H ₉	C ₆ H ₅ MgBr	64 [§]	67 [§]	5
C ₇ H ₇ SO ₃ - <i>n</i> -C ₄ H ₉	C ₆ H ₅ CH ₂ MgCl	25	...	3
C ₇ H ₇ SO ₃ - <i>n</i> -C ₄ H ₉	C ₆ H ₅ CH ₂ MgCl	67	+	5
2 C ₇ H ₇ SO ₃ - <i>n</i> -C ₄ H ₉	C ₆ H ₅ CH ₂ MgCl	26	...	10
C ₇ H ₇ SO ₃ - <i>n</i> -C ₄ H ₉	<i>n</i> -C ₇ H ₁₅ MgBr	14	...	3
C ₇ H ₇ SO ₃ - <i>n</i> -C ₄ H ₉	C ₆ H ₅ OC≡CMgBr	52	...	11
C ₇ H ₇ SO ₃ - <i>i</i> -C ₄ H ₉	C ₆ H ₅ CH ₂ MgCl	33	...	3
C ₇ H ₇ SO ₃ - <i>s</i> -C ₄ H ₉	C ₆ H ₅ CH ₂ MgCl	30	...	3
D(+)-C ₇ H ₇ SO ₃ CH(CH ₃)C ₂ H ₅	C ₂ H ₅ MgBr	...	+ [¶]	8
(-)-C ₇ H ₇ SO ₃ CH(CH ₃)CO ₂ C ₂ H ₅	C ₂ H ₅ MgBr	...	+ [¶]	4
(-)-C ₇ H ₇ SO ₃ CH(CH ₃)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	...	+ [¶]	4
C ₇ H ₇ SO ₃ CH(CH ₃)CO ₂ C ₂ H ₅	C ₆ H ₅ MgBr	...	55	5
C ₇ H ₇ SO ₃ - <i>n</i> -C ₅ H ₁₁	4-BrC ₆ H ₅ MgBr	41	...	7
C ₇ H ₇ SO ₃ - <i>n</i> -C ₅ H ₁₁	C ₆ H ₅ CH ₂ MgCl	45	...	3
C ₇ H ₇ SO ₃ CH ₂ C ₆ H ₄ -4-Br	C ₆ H ₅ C≡CMgBr	50	...	19
C ₇ H ₇ SO ₃ CH ₂ C ₆ H ₅	C ₆ H ₅ CH ₂ MgCl	55 [‡]	...	3
C ₇ H ₇ SO ₃ CH ₂ C ₆ H ₅	4-BrC ₆ H ₄ C≡CMgBr	26	...	19
D(+)-C ₇ H ₇ SO ₃ CH(CH ₃)CH ₂ C ₆ H ₅	C ₆ H ₅ MgBr	...	+ [¶]	8
D(+)-C ₇ H ₇ SO ₃ CH(CH ₃) <i>n</i> -C ₆ H ₁₃	C ₆ H ₅ MgBr	...	+ [¶]	8

[§]In addition to the products here indicated, this reaction also yielded a small amount of phenyl *p*-tolyl sulfone.

[¶]The product reported retains optical activity, presumably with inversion of configuration.

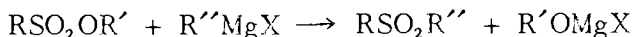
[‡]The yield reported is probably high by reason of inclusion of the Wurtz by-product formed in preparation of the Grignard reagent.

REFERENCES FOR TABLE XXI-II

- (1) Ferns and Lapworth, *Proc. Chem. Soc.*, 28, 18-9 (1912); *J. Chem. Soc.*, 101, 273-87 (1912).
- (2) Gilman and Beaber, *J. Am. Chem. Soc.*, 45, 839-42 (1923).
- (3) Gilman and Beaber, *J. Am. Chem. Soc.*, 47, 518-25 (1925).
- (4) Kenyon, Phillips, and Turley, *J. Chem. Soc.*, 127, 399-417 (1925).
- (5) Gilman and Heck, *J. Am. Chem. Soc.*, 50, 2223-30 (1928).
- (6) Bert, *Compt. rend.*, 186, 373-5 (1928); *Chem. Zentr.*, 1928, I, 1758.
- (7) Roy and Marvel, *J. Am. Chem. Soc.*, 57, 1311-4 (1935).
- (8) Kenyon, Phillips, and Pittman, *J. Chem. Soc.*, 1935, 1072-84.
- (9) Rossander and Marvel, *J. Am. Chem. Soc.*, 50, 1491-6 (1928).

- (10) Gilman and Robinson, *Organic Syntheses*, 10, 4-5 (1930).
 (11) Jacobs, Cramer, and Weiss, *J. Am. Chem. Soc.*, 62, 1849-54 (1940).
 (12) Khitrik, *J. Gen. Chem. (U.S.S.R.)*, 10, 2098-100 (1940); *Chem. Abstr.*, 35, 3961 (1941).
 (13) Bert, *Compt. rend.*, 213, 1015-6 (1941); *Chem. Abstr.*, 37, 4049 (1943).
 (14) Blicke and Leonard, *J. Am. Chem. Soc.*, 68, 1934-6 (1946).
 (15) Sulzbacher and Bergmann, *J. Org. Chem.*, 13, 303-8 (1948).
 (16) Blicke and Burckhalter, *J. Am. Chem. Soc.*, 64, 477-80 (1942).
 (17) Newman and Wotiz, *J. Am. Chem. Soc.*, 71, 1292-7 (1949).
 (18) Johnson, Schwartz, and Jacobs, *J. Am. Chem. Soc.*, 60, 1882-4 (1938).
 (19) Johnson, Jacobs, and Schwartz, *J. Am. Chem. Soc.*, 60, 1885-9 (1938).

In addition to the reactions already discussed, sulfonic esters are capable of undergoing sulfone formation with Grignard reagents.



Although this tendency appears to be intensified in the esters of the alkanesulfonic acids and in the aryl esters of the aryl sulfonic acids, it is not exclusively confined to them, for Gilman and Heck (*loc. cit.*¹²) report the formation of small quantities of phenyl *p*-tolyl sulfone in the reaction of phenylmagnesium bromide with *n*-butyl *p*-toluenesulfonate. Data are summarized in Table XXI-III.

TABLE XXI-III
 REACTIONS OF GRIGNARD REAGENTS WITH ALKANESULFONIC
 ESTERS AND ARYL *p*-TOLUENESULFONATES

(C₇H₇ = *p*-tolyl.)

<u>RSO₂OR'</u>	<u>R''MgX</u>	<u>% R'R''</u>	<u>% RSO₂R''</u>	<u>Ref.</u>
C ₂ H ₅ SO ₃ CH ₃	C ₆ H ₅ MgBr	21	14	3
C ₂ H ₅ SO ₃ C ₂ H ₅	C ₆ H ₅ MgBr	+	+	1,5
C ₂ H ₅ SO ₃ C ₆ H ₅	C ₆ H ₅ MgBr	6-11 †	74	3
(CH ₂) ₅ CHSO ₃ C ₂ H ₅	C ₆ H ₅ MgBr	18	...	4
C ₇ H ₇ SO ₃ C ₆ H ₅	C ₆ H ₅ MgBr	...	44	2
C ₇ H ₇ SO ₃ C ₆ H ₅	C ₇ H ₇ MgBr	...	45	2
C ₇ H ₇ SO ₃ C ₆ H ₅	4-CH ₃ OC ₆ H ₄ MgBr	...	82	2
C ₇ H ₇ SO ₃ C ₆ H ₅	1-C ₁₀ H ₇ MgBr	...	71	2
C ₇ H ₇ SO ₃ C ₆ H ₄ -2-CH ₃	C ₆ H ₅ MgBr	...	43	2
(C ₇ H ₇ SO ₃ C ₆ H ₄ -4-) ₂	C ₆ H ₅ MgBr	...	61	2

* Present in small amount only.

† Principal product.

‡ The yield of biphenyl reported (1-2 g. from 25 g. ester) is attributable in large part, and perhaps altogether, to Wurtz byproduct formation in preparation of the Grignard reagent.

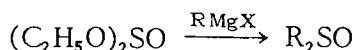
REFERENCES FOR TABLE XXI-III

- (1) Ferns and Lapworth, *Proc. Chem. Soc.*, 28, 18-9 (1912); *J. Chem. Soc.*, 101, 273-87 (1912).
 (2) Gilman, Beaber, and Myers, *J. Am. Chem. Soc.*, 47, 2047-52 (1925).
 (3) Gilman and Robinson, *Bull. soc. chim.*, [4], 45, 636-41 (1929).
 (4) Gilman and Heck, *J. Am. Chem. Soc.*, 50, 2223-30 (1928).
 (5) Strecker, *Ber.*, 43, 1131-6 (1910).

Other papers bearing on the reactions of Grignard reagents with sulfonic esters, but containing little specific information, have been published by Wedekind and Schenk¹⁴ and by Mine.¹⁵

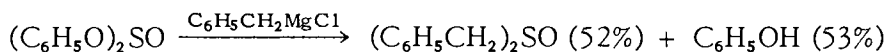
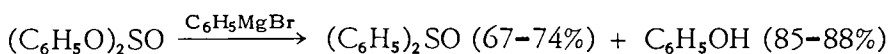
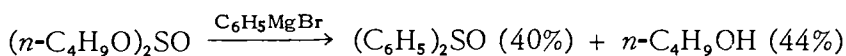
ESTERS OF OTHER SULFUR ACIDS

Sulfites. Strecker¹⁶ reported reactions of phenylmagnesium bromide and benzylmagnesium chloride with ethyl sulfite to yield sulfoxides.

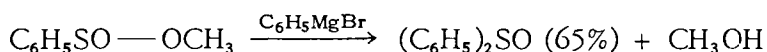
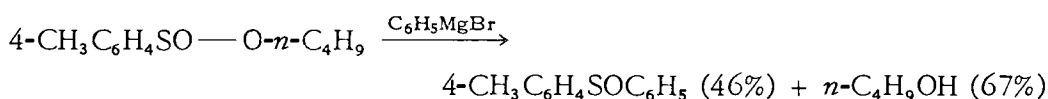
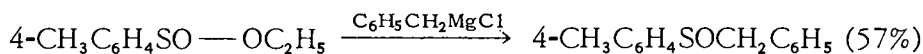
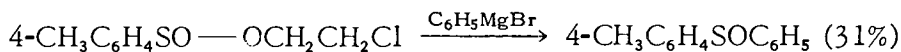


Bert¹⁷ recommended *n*-butyl sulfite as preferable to thionyl chloride for the Grignard preparation of sulfoxides, and reported having effected such sulfoxide preparations with *n*-butyl-, phenyl-, and *p*-cumylmagnesium bromides and with *p*-isopropylbenzylmagnesium chloride.

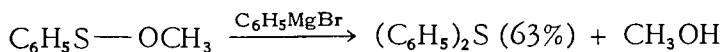
Gilman *et al.*¹⁸ have shown that the alcohols (or phenols) which might be expected as byproducts of such reactions are also formed.



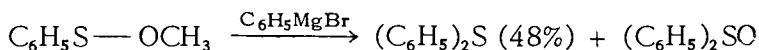
Sulfinates. Gilman *et al.*^{18,19} have further shown that the sulfinates also react with Grignard reagents to form sulfoxides and alcohols.



Sulfenates. Methyl benzenesulfenate reacts similarly with phenylmagnesium bromide to form phenyl sulfide and methyl alcohol (Gilman and Robinson, *loc. cit.*^{19b}).



Gilman, Robinson, and Beaber (*loc. cit.*¹⁸) report the isolation of some sulfoxide from this reaction mixture.



¹⁴ Wedekind and Schenk, *Ber.*, 54B, 1604–12 (1921).

¹⁵ Mine, *J. Chem. Soc. Japan*, 55, 905–9, 1087–90 (1934); 56, 200–9, 1112–7 (1935); *Chem. Abstr.*, 29, 753, 5427, 7940 (1935); 30, 441 (1936).

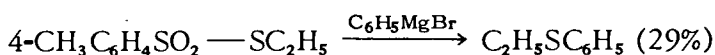
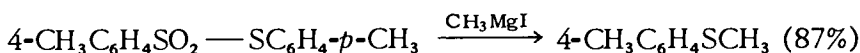
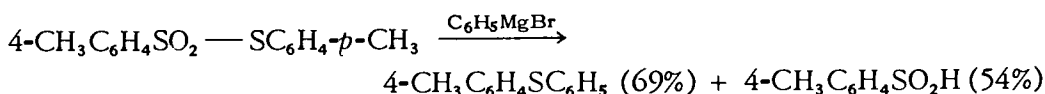
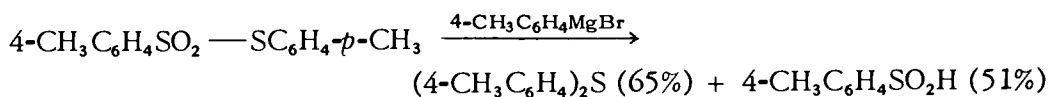
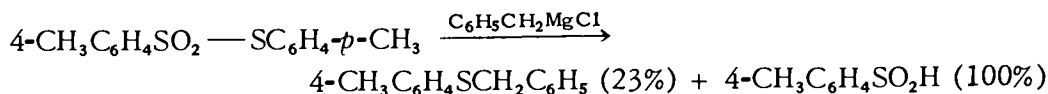
¹⁶ Strecker, *Ber.*, 43, 1131–6 (1910).

¹⁷ Bert, *Compt. rend.*, 178, 1826–8 (1924); *Chem. Abstr.*, 18, 2496 (1924).

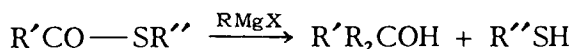
¹⁸ Gilman, Robinson, and Beaber, *J. Am. Chem. Soc.*, 48, 2715–8 (1926).

¹⁹ (a) Gilman and Beaber, *J. Am. Chem. Soc.*, 45, 839–42 (1923); (b) Gilman and Robinson, *Bull. soc. chim.*, [4], 45, 636–41 (1929).

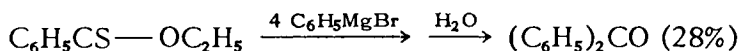
Thiolsulfonates. The so-called "disulfoxides," actually thiolsulfonates, react with Grignard reagents to form sulfides and sulfinic acids (Gilman *et al.*²⁰).



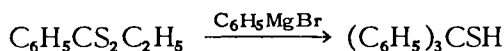
Thiocarboxylates. Hepworth and Clapham²¹ found that alkyl thiocarboxylic esters react with Grignard reagents to yield mercaptans and tertiary alcohols, an observation which has been confirmed by Gilman, Robinson, and Beaber (*loc. cit.*¹⁸).



According to the latter authors, ethyl thionebenzoate, upon treatment with excess phenylmagnesium bromide, forms a sulfur-containing intermediate which, upon standing under hydrolytic conditions, liberates benzophenone.

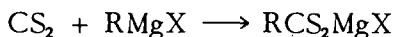


The corresponding dithiobenzoate, however, is said to yield triphenylmethyl mercaptan (Gilman, Robinson, and Beaber, *loc. cit.*¹⁸).



CARBON DISULFIDE AND CARBONYL SULFIDE

Insofar as they have been studied the reactions of carbon disulfide with Grignard reagents appear to be altogether analogous to the corresponding reactions of carbon dioxide (*q.v.*, Chapter XIII).



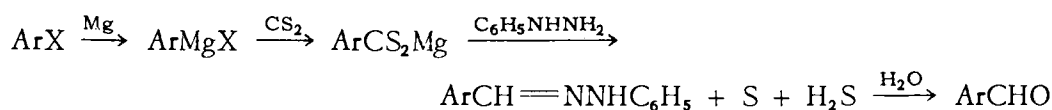
Undoubtedly the initial product of reaction is, like its oxygen analog, capable of further reaction with excess Grignard reagent. Moreover, the dithiocarboxylic acids are both sensitive to atmospheric oxidation and susceptible to thermal decomposition. It is not surprising therefore that early investigators, who employed the "normal" order of addition, and who took no special precautions for cooling or oxygen exclusion, either

²⁰ Gilman, Smith, and Parker, *J. Am. Chem. Soc.*, 47, 851–60 (1925).

²¹ Hepworth and Clapham, *J. Chem. Soc.*, 119, 1188–99 (1921).

reported very low yields of dithiocarboxylic acids or were reticent on the subjects of yields.

Wuyts *et al.*²² found that aromatic dithiocarboxylic acids could be converted to derivatives of aromatic aldehydes by treatment with phenylhydrazine, semicarbazide, or hydroxylamine, thus providing a means for the conversion of an aryl halide to the corresponding aldehyde.



They employed a well-conceived experimental technique, operating under nitrogen, and adding the Grignard reagent slowly to an excess of carbon disulfide with moderative cooling. They report yields of 46 and 53 per cent for *p*-bromo- and *p*-chlorodithiobenzoic acids, respectively.

Available data are summarized in Table XXI-IV.

TABLE XXI-IV

REACTIONS OF GRIGNARD REAGENTS WITH CARBON DISULFIDE

<u>RMgX</u>	<u>RCS₂H</u>	<u>Ref.</u>
CH ₃ MgI	CH ₃ CS ₂ H (17.9%)	4a,5,9
C ₂ H ₅ MgBr	C ₂ H ₅ CS ₂ H (11.9%)	4b,5
<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ CS ₂ H (5.0%)	4b
<i>i</i> -C ₄ H ₉ MgBr	<i>i</i> -C ₄ H ₉ CS ₂ H (4.4%)	4b
<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₅ H ₁₁ CS ₂ H (4.4%)	4b
4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ CS ₂ H (46.0%)	10,2
4-ClC ₆ H ₄ MgBr	4-ClC ₆ H ₄ CS ₂ H (53.0%)	11
C ₆ H ₅ MgBr	C ₆ H ₅ CS ₂ H (>9.0%)*	6,2,8,9,10,11
(CH ₂) ₅ CHMgX	(CH ₂) ₅ CHCS ₂ H	9
C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ CS ₂ H (>3.0%) [†]	5,1,2,9
2-CH ₃ C ₆ H ₄ MgBr	2-CH ₃ C ₆ H ₄ CS ₂ H (>59.6%) [‡]	12,8,9,10,11
4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ CS ₂ H (>23.3%) [‡]	12,9,10,11
2,4,5-(CH ₃) ₃ C ₆ H ₂ MgBr	2,4,5-(CH ₃) ₃ C ₆ H ₂ CS ₂ H (>43.9%) [‡]	12
2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	2,4,6-(CH ₃) ₃ C ₆ H ₂ CS ₂ H (>2.2%) [‡]	12
1-C ₁₀ H ₇ MgBr	1-C ₁₀ H ₇ CS ₂ H	2,8,9,10,11
2-C ₁₀ H ₇ MgBr	2-C ₁₀ H ₇ CS ₂ H	10,11
2-CH ₃ -5- <i>i</i> -C ₃ H ₇ C ₆ H ₃ MgBr	2-CH ₃ -5- <i>i</i> -C ₃ H ₇ C ₆ H ₃ CS ₂ H	7
2,3,5,6-(CH ₃) ₄ C ₆ HMgBr	? §	12
C ₁₀ H ₁₇ MgCl [¶]	C ₁₀ H ₇ CS ₂ H	3
(CH ₃) ₅ C ₆ MgBr	? §	12
(C ₆ H ₅) ₂ C=C(C ₆ H ₅)MgBr	(C ₆ H ₅) ₂ C=C(C ₆ H ₅)CS ₂ H	13

* The recorded yield is that of the ester obtained upon treatment of the Grignard reaction product with ethyl sulfate.

[†] The recorded yield is that of the ester obtained upon treatment of the Grignard reaction product with methyl sulfate.

[‡] The recorded yield is that of the aldehyde obtained by the method of Wuyts (8,9,10,11).

§ No aldehyde was obtained by the method of Wuyts (8,9,10,11).

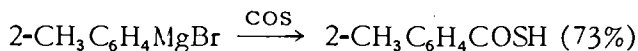
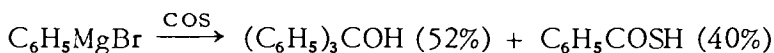
[¶] From pinene hydrochloride.

²²Wuyts, *Bull. soc. chim. Belg.*, 38, 194-204 (1929); 39, 58-66 (1930); Wuyts, Berman, and Lacourt, *ibid.*, 40, 665-72 (1931); Wuyts and Koeck, *ibid.*, 41, 196-201 (1932).

REFERENCES FOR TABLE XXI-IV

- (1) Houben and Kesselkaul, *Ber.*, 35, 3695-6 (1902).
- (2) Houben, *Ber.*, 39, 3219-33 (1906).
- (3) Houben and Doescher, *Ber.*, 39, 3503-9 (1906).
- (4) Houben and Pohl (*a*) *Ber.*, 40, 1303-7 (1907); (*b*) *ibid.*, 40, 1725-30 (1907).
- (5) Houben and Schulze, *Ber.*, 43, 2481-5 (1910).
- (6) Gilman, Robinson, and Beaber, *J. Am. Chem. Soc.*, 48, 2715-8 (1926).
- (7) Wheeler and Thomas, *J. Am. Chem. Soc.*, 50, 3106-9 (1928).
- (8) Wuyts, *Bull. soc. chim. Belg.*, 38, 195-204 (1929).
- (9) Wuyts, *Bull. soc. chim. Belg.*, 39, 58-66 (1930).
- (10) Wuyts, Berman, and Lacourt, *Bull. soc. chim. Belg.*, 40, 665-72 (1931).
- (11) Wuyts and Koeck, *Bull. soc. chim. Belg.*, 41, 196-201 (1932).
- (12) Smith and Nichols, *J. Org. Chem.*, 6, 489-506 (1941).
- (13) Koelsch, *J. Am. Chem. Soc.*, 54, 2045-8 (1932).

As products of the reactions of carbonyl sulfide with several Grignard reagents, Weigert²³ isolated tertiary alcohols and thiocarboxylic acids.

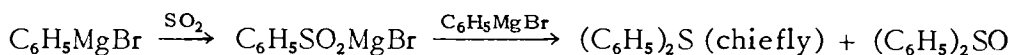


SULFUR DIOXIDE

In his classical paper describing early work on the preparations and reactions of organomagnesium halides, Grignard²⁴ expressed the intention of investigating "the action on organomagnesium compounds of a certain number of other gases [than carbon dioxide], and in particular that of sulfurous anhydride." Apparently more engrossing problems intervened.

Rosenheim and Singer,²⁵ reasoning that, by analogy with the behavior of carbon dioxide, sulfur dioxide should react with Grignard reagents to form salts of sulfinic acids, investigated several such reactions and obtained the expected products in 50-60 percent yields. Other reports of similar reactions are recorded in Table XXI-V.

The sulfinates so formed are capable of further reaction with excess Grignard reagent, as was shown by Oddo.²⁶



²³Weigert, *Ber.*, 36, 1007-13 (1903).

²⁴Grignard, *Ann. chim.*, [7], 24, 433-90 (1901).

²⁵Rosenheim and Singer, *Ber.*, 37, 2152-4 (1904).

²⁶Oddo, *Gazz. chim. ital.*, 41, I, 11-6 (1911); *Chem. Zentr.*, 1911, I, 1116; *Chem. Abstr.*, 5, 2635 (1911).

TABLE XXI-V

REACTIONS OF GRIGNARD REAGENTS WITH SULFUR DIOXIDE

<u>RMgX</u>	<u>RSO₂H</u>	<u>Ref.</u>
C ₂ H ₅ MgX	C ₂ H ₅ SO ₂ H (50–60%)	1
RMgBr*	RSO ₂ H*	9
<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ SO ₂ H (50–60%)	1
<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ SO ₂ H (69%)	10,5
<i>i</i> -C ₅ H ₁₁ MgBr	<i>i</i> -C ₅ H ₁₁ SO ₂ H	5
C ₆ H ₅ MgBr	C ₆ H ₅ SO ₂ H (50–60%)	1,4
(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CHSO ₂ H	2
(CH ₂) ₅ CHMgCl	(CH ₂) ₅ CHSO ₂ H	5,7
C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ SO ₂ H	8
2-CH ₃ C ₆ H ₄ CH ₂ MgBr	2-CH ₃ C ₆ H ₄ CH ₂ SO ₂ H	8
3-CH ₃ C ₆ H ₄ CH ₂ MgBr	3-CH ₃ C ₆ H ₄ CH ₂ SO ₂ H + 2,6-(CH ₃) ₂ C ₆ H ₃ SO ₂ H	8
4-CH ₃ C ₆ H ₄ CH ₂ MgBr	4-CH ₃ C ₆ H ₄ CH ₂ SO ₂ H	8
3,3-Dimethylcyclohexyl-MgBr (10.25 g. C ₈ H ₁₅ Br)	C ₈ H ₁₅ SO ₂ H (yielding 4.55 g. C ₈ H ₁₅ SO ₃ Na)	12
<i>n</i> -C ₈ H ₁₇ MgBr	<i>n</i> -C ₈ H ₁₇ SO ₂ H (41.6%)	10
<i>n</i> -C ₉ H ₁₉ MgBr	<i>n</i> -C ₉ H ₁₉ SO ₂ H (37.6%)	10
C ₁₀ H ₁₇ MgCl†	C ₁₀ H ₁₇ SO ₂ H	3
<i>n</i> -C ₁₀ H ₂₁ MgBr	<i>n</i> -C ₁₀ H ₂₃ SO ₂ H (34.5%)	10
4-CH ₃ C ₆ H ₄ (CH ₃) ₂ CCH ₂ MgCl	4-CH ₃ C ₆ H ₄ (CH ₃) ₂ CCH ₂ SO ₂ H (>52%)‡	6
<i>n</i> -C ₁₁ H ₂₃ MgBr	<i>n</i> -C ₁₁ H ₂₃ SO ₂ H (49.8%)	10
<i>n</i> -C ₁₂ H ₂₅ MgBr	<i>n</i> -C ₁₂ H ₂₅ SO ₂ H (56.5%)	10
<i>n</i> -C ₁₂ H ₂₅ MgBr	(<i>n</i> -C ₁₂ H ₂₅ SO ₂) ₂ Mg · 2 H ₂ O (80%)§	11
<i>n</i> -C ₁₂ H ₂₅ MgBr	<i>n</i> -C ₁₂ H ₂₅ SO ₂ S- <i>n</i> -C ₁₂ H ₂₅ ¶	11
<i>n</i> -C ₁₃ H ₂₇ MgBr	<i>n</i> -C ₁₃ H ₂₇ SO ₂ H (38.7%)	10
<i>n</i> -C ₁₄ H ₂₉ MgBr	<i>n</i> -C ₁₄ H ₂₉ SO ₂ H (39.2%)	10
<i>n</i> -C ₁₅ H ₃₁ MgBr	<i>n</i> -C ₁₅ H ₃₁ SO ₂ H (43.0%)	10
<i>n</i> -C ₁₆ H ₃₃ MgBr	<i>n</i> -C ₁₆ H ₃₃ SO ₂ H (57.2%)	10

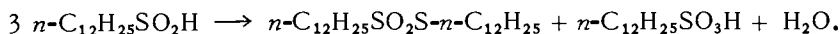
* R = C₂H₅, *n*-C₃H₇, *n*-C₄H₉, *n*-C₅H₁₁.

† From pinene hydrochloride.

‡ The figure recorded represents the yield of the sulfonic acid obtained upon oxidation of the Grignard product.

§ By treatment of the Grignard reagent from 125 g. *n*-C₁₂H₂₅Br with 32 g. SO₂ at -40 to -35°, and addition of the reaction mixture to cold aqueous NH₄Cl.

¶ By treatment of the Grignard reagent from 200 g. *n*-C₁₂H₂₅Br with a threefold excess of SO₂ at -35°. According to Marvel and Johnson (11), 1-dodecanesulfonic acid is slowly converted, on standing, to 1-dodecyl 1-dodecanethiolsulfonate. They attribute the conversion to the disproportionation reaction:



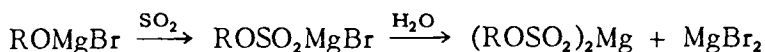
REFERENCES FOR TABLE XXI-V

- (1) Rosenheim and Singer, *Ber.*, 37, 2152–4 (1904).
- (2) Borsche and Lang, *Ber.*, 38, 2766–9 (1905).
- (3) Houben and Doescher, *Ber.*, 39, 3503–9 (1906).
- (4) Oddo, *Gazz. chim. ital.*, 41, I, 11–6 (1911); *Chem. Zentr.*, 1911, I, 1116; *Chem. Abstr.*, 5, 2635 (1911).
- (5) von Braun and Weissbach, *Ber.*, 63B, 2836–47 (1930).
- (6) Archer, Malkemus, and Suter, *J. Am. Chem. Soc.*, 67, 43–5 (1945).

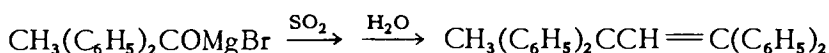
- (7) Mousseron and Granger, *Bull. soc. chim. France*, 1946, 251-6; *Chem. Abstr.*, 40, 6430 (1946).
- (8) Mousseron and Nguyen-Phuoc-Du, *Bull. soc. chim. France*, 1948, 91-6; *Chem. Abstr.*, 42, 4551 (1948).
- (9) Houlton and Tartar, *J. Am. Chem. Soc.*, 60, 544-8 (1938).
- (10) Allen, *J. Org. Chem.*, 7, 23-30 (1942).
- (11) Marvel and Johnson, *J. Org. Chem.*, 13, 822-9 (1948).
- (12) von Doering and Beringer, *J. Am. Chem. Soc.*, 71, 2221-6 (1949).

Truchet²⁷ obtained a mixture of ethyl phenyl sulfoxide and ethyl phenyl sulfide upon treatment of benzenesulfinic acid with an excess of ethylmagnesium bromide. Burton and Davy²⁸ have reported a 51 percent yield of sulfoxide resulting from the treatment of *p*-toluenesulfinic acid with excess cold ethereal phenylmagnesium bromide. Similarly, Gilman *et al.*²⁹ report a 23 percent yield of benzyl *p*-tolyl sulfoxide (with 57 percent sulfinic acid recovery) upon treatment of *p*-toluenesulfinic acid with benzylmagnesium chloride.

Schmidt-Nickels³⁰ treated triphenylmethoxymagnesium bromide and the corresponding bromomagnesium derivative of 9-phenyl-9-fluorene with sulfur dioxide and obtained the ester salts of sulfurous acid.



However, when α,α -diphenylethoxymagnesium bromide was similarly treated a condensation product was obtained.



ACID HALIDES

Sulfonyl halides. The products commonly reported as resulting from the reactions of Grignard reagents with sulfonyl chlorides are sulfones, sulfoxides, and sulfides. Wedekind and Schenk³¹ and Hepworth and Clapham³² sought to account for the secondary products as resulting from further reaction of the Grignard reagents with the highly stable sulfones presumed to be the primary products of reaction. This despite the fact that the latter investigators observed no reaction when phenyl sulfone was refluxed with methylmagnesium iodide in toluene for eighteen hours, and found phenyl benzyl sulfone and trimethylenetrisulfone similarly inert.

It was subsequently shown by Gilman and Fothergill³³ that sulfonyl chlorides, like the corresponding sulfonic esters (*q.v.*), are capable of

²⁷ Truchet, *Compt. rend.*, 191, 296-9 (1930); *Chem. Zentr.*, 1930, 11, 3019; *Chem. Abstr.*, 25, 501 (1931).

²⁸ Burton and Davy, *J. Chem. Soc.*, 1948, 528-9.

²⁹ Gilman, Smith, and Parker, *J. Am. Chem. Soc.*, 47, 851-60 (1925).

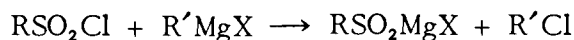
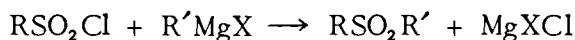
³⁰ Schmidt-Nickels, *Ber.*, 62B, 917-9 (1929).

³¹ Wedekind and Schenk, *Ber.*, 54B, 1604-12 (1921).

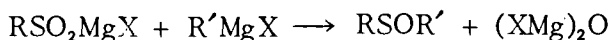
³² Hepworth and Clapham, *J. Chem. Soc.*, 119, 188-98 (1921).

³³ Gilman and Fothergill, *J. Am. Chem. Soc.*, 51, 3501-8 (1929).

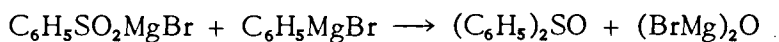
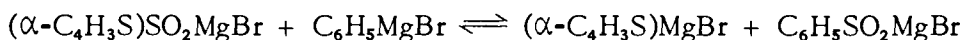
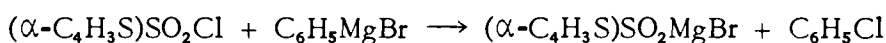
reacting with Grignard reagents in more than one way:



They suggested that sulfoxide formation might be attributed to the reaction:



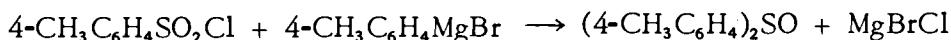
Burton and Davy³⁴ report that the principal product of the reaction of thiophene-2-sulfonyl chloride with phenylmagnesium bromide (twenty-two hours reflux in benzene) is phenyl sulfoxide (possibly admixed with a little 2-thienyl phenyl sulfoxide). To account for this product they propose a reaction scheme similar to that of Gilman and Fothergill (*loc. cit.*³³), but including an exchange step (presumably an equilibrium).



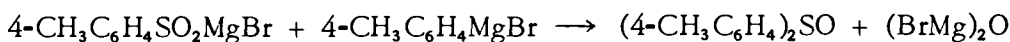
Whether or not Grignard reagents prepared from sublimed magnesium would react similarly apparently has not been determined.

Burton and Hu³⁵ reasoned that if such an exchange does in fact take place it should be possible to demonstrate the presence of the resultant 2-thienyl Grignard reagent by carbonation of the reaction mixture. When they passed carbon dioxide (for twenty hours) into such a reaction mixture which had previously been refluxed for twenty hours they were indeed able to recover a 30 percent yield of thiophene-2-carboxylic acid.

The concept of such an exchange might also be invoked to account for the small amount of *p*-tolyl sulfoxide which Wedekind and Schenk³⁶ detected among the products of the reaction of *p*-toluenesulfonyl chloride with ethylmagnesium bromide.



and/or



The occurrence of sulfides among the products of reaction of Grignard reagents with sulfinates (Oddo,²⁶ Truchet²⁷—see preceding section) and with thionyl chloride (Oddo,²⁶ Grignard and Zorn³⁷) is strongly suggestive that sulfoxides are capable of undergoing Grignard reduction. This possibility is discussed in the section on Sulfoxides p. 1296.

A summary of reported reactions of Grignard reagents with sulfonyl halides is recorded in Table XXI-VI. Steinkopf and Jaeger³⁸ report that

³⁴ Burton and Davy, *J. Chem. Soc.*, 1948, 528-9.

³⁵ Burton and Hu, *J. Chem. Soc.*, 1949, 258.

³⁶ Wedekind and Schenk, *Ber.*, 54B, 1604-12 (1921).

³⁷ Grignard and Zorn, *Compt. rend.*, 150, 1177-9 (1910); *Chem. Zentr.*, 1910, II, 143.

³⁸ Steinkopf and Jaeger, *J. prakt. Chem.*, [2], 128, 63-88 (1930).

TABLE XXI-VI
REACTIONS OF GRIGNARD REAGENTS WITH SULFONYL HALIDES

RSO_2X	$\text{R}'\text{MgX}'$	$\text{RSO}_2\text{R}'(\%)*$	$\text{RSO}_2\text{H}(\%)*$	$\text{R}'\text{X}(\%)*$	$\text{RSOR}'(\%)*$	$\text{RSR}'(\%)*$	Ref.
$(\alpha\text{-C}_4\text{H}_9\text{S})\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{MgBr}$	...	...	...	$+(?)^\dagger$	...	7,8
$\text{C}_6\text{H}_5\text{SO}_2\text{F}$	CH_3MgI}	+	...	...	...	...	5
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	CH_3MgI	...	53.0	27.0	...	...	6
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$\text{C}_2\text{H}_5\text{MgBr}$	...	32.0	33.0	...	...	6
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$\text{C}_2\text{H}_5\text{MgBr}$	+	...	...	+	+	3
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{MgBr}$	...	+	+	...	...	1
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{MgBr}$	...	...	...	+	+	2
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{MgBr}$	+	...	...	+	...	3
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{MgBr}$	35.0	0.5	16.3	...	...	4
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{CH}_2\text{MgCl}$	+	...	...	41.7	+	3
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{CH}_2\text{MgCl}$	2.9	...	60.0	...	...	4
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$4\text{-CH}_3\text{C}_6\text{H}_4\text{MgBr}$	...	+	...	...	...	7
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$4\text{-CH}_3\text{C}_6\text{H}_4\text{MgBr}$	17.5	46.4	27.0	...	...	4
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$n\text{-C}_5\text{H}_{11}\text{C}\equiv\text{CMgBr}$	...	20.0	37.0	...	...	6
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{C}\equiv\text{CMgBr}$	...	1.2	13.7	...	...	4
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{C}\equiv\text{CMgBr}$	...	25.0	35.0	...	...	6
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{CH}=\text{CHMgBr}$	...	39.6	40.4	...	...	4
$\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$	$1\text{-C}_{10}\text{H}_7\text{MgBr}$	...	...	39.7	...	...	4
$4\text{-CH}_3\text{C}_6\text{H}_4\text{-1,3-(SO}_2\text{F)}_2$	$\text{C}_6\text{H}_5\text{MgBr}$	+	...	...	...	...	5
$4\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{Cl}$	CH_3MgI}	...	...	...	+	+	2
$4\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{Cl}$	$\text{C}_2\text{H}_5\text{MgBr}$	...	+	...	$+\dagger$	+	2
$4\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{Cl}$	$\text{C}_2\text{H}_5\text{MgBr}$	...	37.0	22.0	...	...	6
$4\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{Cl}$	$n\text{-C}_4\text{H}_9\text{MgBr}$	...	60.6	8.7	...	...	4

* A plus sign indicates that the product has been reported without statement of yield.

\dagger It is reported by Burton and Davy (7) that the principal product of this reaction is phenyl sulfoxide ($\text{R}'_2\text{SO}$), possibly admixed with a little 2-thienyl phenyl sulfoxide (RSOR').

\dagger Wedekind and Schenk (2) also detected a small amount of *p*-tolyl sulfoxide (R_2SO) among the products of this reaction.

TABLE XXI-VI (Continued)

RSO_2X	$\text{R}'\text{MgX}'$	$\text{RSO}_2\text{R}'(\%)*$	$\text{RSO}_2\text{H}(\%)*$	$\text{R}'\text{X}(\%)*$	$\text{RSOR}'(\%)*$	$\text{RSR}'(\%)*$	Ref.
4- $\text{CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{MgBr}$	32.9	10.7	11.0	...	...	4
4- $\text{CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{MgBr}$	+	...	...	+	...	2
4- $\text{CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{MgBr}$	...	...	19.8 [†]	62.0 [†]	...	7
4- $\text{CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{MgBr}$	...	...	...	40.0 [‡]	38.0 [‡]	7
4- $\text{CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{MgBr}$	27.5 [§]	...	24.2 [§]	7
4- $\text{CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{Cl}$	$(\text{CH}_2)_5\text{CHMgBr}$	...	67.1	66.3	...	...	4
4- $\text{CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{C}\equiv\text{CMgBr}$	...	27.0	33.0	...	...	6
4- $\text{CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{Br}$	$\text{C}_6\text{H}_5\text{MgBr}$	...	30.2	53.8	...	...	4
4- $\text{CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{I}$	$\text{C}_6\text{H}_5\text{MgBr}$	...	11.8	65.1	...	...	4
1- $\text{C}_{10}\text{H}_7\text{SO}_2\text{Cl}$	$\text{C}_6\text{H}_5\text{MgBr}$	13.0	...	24.5	...	...	4

* A plus sign indicates that the product has been reported without statement of yield.

[†] Twenty-two hours reflux in benzene.

[‡] Eighteen hours reflux in benzene.

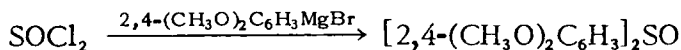
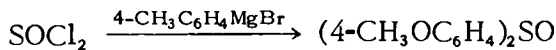
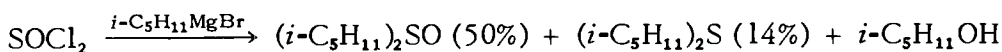
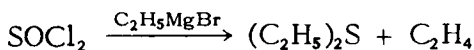
[§] Reaction at -5° in ether.

REFERENCES FOR TABLE XXI-VI

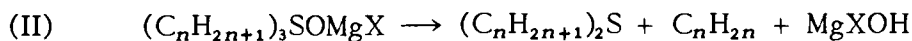
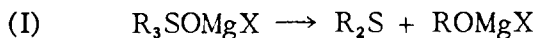
- (1) Oddo, *Atti accad. Lincei*, [5], 14,1, 169-74 (1905); *Chem. Zentr.*, 1905,1, 1145.
- (2) Wedekind and Schenk, *Ber.*, 54B, 1604-12 (1921).
- (3) Hepworth and Clapham, *J. Chem. Soc.*, 119, 1188-98 (1921).
- (4) Gilman and Fothergill, *J. Am. Chem. Soc.*, 51, 3501-8 (1929).
- (5) Steinkopf and Jaeger, *J. prakt. Chem.*, [2], 128, 63-88 (1930).
- (6) Truchet, *Ann. chim.*, [10], 16, 309-419 (1931).
- (7) Burton and Davy, *J. Chem. Soc.*, 1948, 528-9.
- (8) Burton and Hu, *J. Chem. Soc.*, 1949, 258.

the reaction of methylmagnesium iodide with benzenesulfonyl fluoride produces, in addition to the sulfone, an unidentified acidic substance of the empirical formula $C_{13}H_{14}O_4S_2$. The reaction of phenylmagnesium bromide with toluene-2,4-disulfonyl fluoride yields a similar byproduct ($C_{25}H_{22}O_4S$).

Thionyl and sulfuryl chlorides. Grignard and Zorn³⁹ investigated the reactions of several organomagnesium halides with thionyl chloride and found the products to be sulfoxides and sulfides.

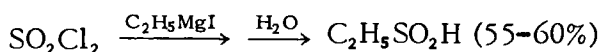
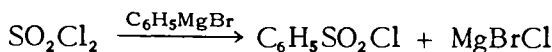


Sulfide formation was attributed to further reaction of the Grignard reagent with the sulfoxide initially formed. It was postulated that the hypothetical sulfonium hydroxide derivative so formed may decompose in either of two ways:



Strecker⁴⁰ obtained sulfoxides by treatment of thionyl chloride with phenylmagnesium bromide and benzylmagnesium chloride. With ethylmagnesium iodide, Oddo⁴¹ obtained ethyl sulfide, and with phenylmagnesium bromide, a mixture of sulfide and sulfoxide, chiefly the former.

Oddo⁴² has also investigated reactions of sulfuryl chloride.



³⁹ Grignard and Zorn, *Compt. rend.*, 150, 1177-9 (1910); *Chem. Zentr.*, 1910,II, 143.

⁴⁰ Strecker, *Ber.*, 43, 1131-6 (1910).

⁴¹ Oddo, *Gazz. chim. ital.*, 41,1, 11-6 (1911); *Chem. Zentr.*, 1911,1, 1116; *Chem. Abstr.*, 5, 2635 (1911).

⁴² Oddo, *Atti accad. Lincei*, [5], 14,1, 169-74 (1905); *Chem. Zentr.*, 1905,1, 1145.

Cherbuliez and Schnauder⁴³ have found that when the Grignard reagent is a bromide there is a considerable exchange of halogen between the initial products of reaction. Apparently this is not so when the Grignard reagent is an iodide. Their data are summarized in Table XXI-VII. Phenylmagnesium iodide is said to react very feebly with sulfuryl chloride (no figures are given).

TABLE XXI-VII

REACTIONS OF GRIGNARD REAGENTS WITH SULFURYL CHLORIDE

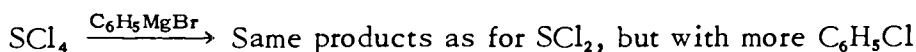
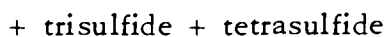
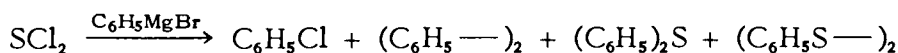
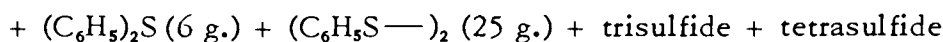
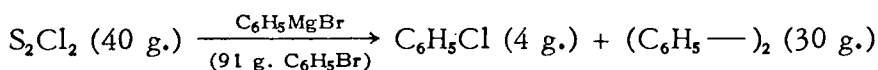
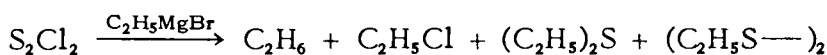
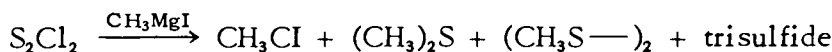
<u>RMgX</u>	<u>RSO₂X (%)</u>
CH ₃ MgBr	CH ₃ SO ₂ Br (21)
CH ₃ MgI	CH ₃ SO ₂ Cl (26)
C ₂ H ₅ MgCl	C ₂ H ₅ SO ₂ Cl (31)
C ₂ H ₅ MgBr	C ₂ H ₅ SO ₂ Br (35)
C ₂ H ₅ MgI	C ₂ H ₅ SO ₂ Cl (32)
C ₆ H ₅ MgBr	C ₆ H ₅ SO ₂ X (5)*
C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ SO ₂ Cl (34)

* The product was a mixture of bromide and chloride in the ratio 0.78:0.22.

Chlorosulfonates. Hepworth and Clapham⁴⁴ report that the reaction of ethylmagnesium bromide with ethyl chlorosulfonate yields ethyl sulfoxide and ethyl sulfide.

SULFUR CHLORIDES

Strecker⁴⁵ treated sulfur monochloride with phenylmagnesium bromide and isolated phenyl disulfide. Ferrario⁴⁶ investigated this and other reactions of sulfur monochloride in somewhat more detail, as well as reactions of sulfur dichloride and tetrachloride. His findings are summarized in the following equations.



⁴³ Cherbuliez and Schnauder, *Helv. Chim. Acta*, 6, 249-57 (1923).

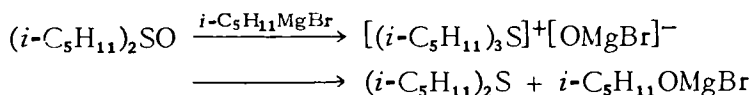
⁴⁴ Hepworth and Clapham, *J. Chem. Soc.*, 119, 1188-98 (1921).

⁴⁵ Strecker, *Ber.*, 43, 1131-6 (1910).

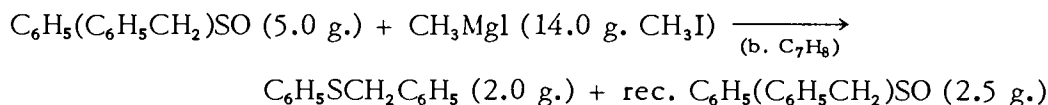
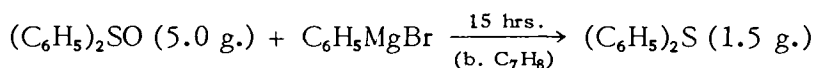
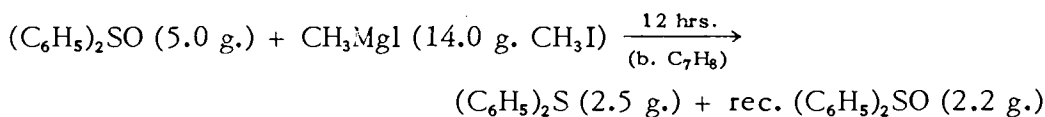
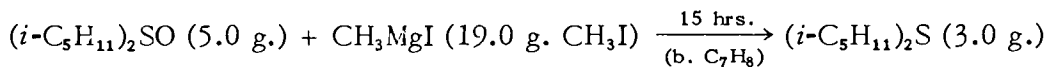
⁴⁶ Ferrario, *Bull. soc. chim.*, [4], 7, 518-27 (1910).

SULFOXIDES

From the results of his work with Zorn on the reactions of organomagnesium halides with thionyl chloride (*q.v.*), Grignard⁴⁷ drew the conclusion that, whereas aryl sulfoxides are inert as regards further reaction with the Grignard reagent, alkyl sulfoxides may react additively. He accounted for the isoamyl sulfide and isoamyl alcohol formed in the isoamylmagnesium bromide reaction by postulating the formation of an intermediate sulfonium hydroxide derivative capable of decomposing in the manner indicated below:



It was subsequently shown by Hepworth and Clapham⁴⁸ that operation at sufficiently elevated temperatures (as in boiling toluene solution) brings about reaction of the aryl sulfoxides also. Their results are summarized in the following equations:



The evident stability of the sulfides under the reaction conditions imposed is sufficient evidence of their inertia toward Grignard reagents (however, see also the section on Thio and Seleno Ethers, Chapter XV). When 5.5 g. of phenyl sulfone was refluxed in toluene solution with methylmagnesium iodide for eighteen hours it was possible to recover 4.0 g. of sulfone, and no traces of sulfide or sulfonium base could be detected.

Unfortunately Hepworth and Clapham established no material balance between reactants and products, so that their experiments constitute no commentary on Grignard's hypothesis concerning the course of the reaction. More recently, however, Wildi *et al.*⁴⁹ have demonstrated that arylmagnesium halides are capable of combining with phenyl sulfoxide to form triarylsulfonium bases. They refluxed the reactants in benzene so-

⁴⁷ Grignard and Zorn, *Compt. rend.*, 150, 1177-9 (1910); *Chem. Zentr.*, 1910, II, 143.

⁴⁸ Hepworth and Clapham, *J. Chem. Soc.*, 119, 1188-98 (1921).

⁴⁹ Wildi, Taylor, and Potratz, *J. Am. Chem. Soc.*, 73, 1965-7 (1951).

lution under an atmosphere of nitrogen for periods of the order of twenty-four hours and then treated the reaction mixtures with relatively concentrated hydrobromic acid. The following crystalline triarylsulfonium bromides were isolated in the indicated percentage yields: $[(C_6H_5)_3S]^+Br^-$ (49.4); $[3-CH_3C_6H_4(C_6H_5)_2S]^+Br^-$ (23.4); $[4-CH_3C_6H_4(C_6H_5)_2S]^+Br^-$ (34.1); $[2,5-(CH_3)_2C_6H_3(C_6H_5)_2S]^+Br^-$ (12.1).

Apparently the α,β -unsaturated sulfoxides exhibit some characteristic peculiarities, for Kohler and Potter^{49.1} report that styryl *p*-tolyl sulfoxide, when treated with ethylmagnesium bromide, yields, in addition to ethyl *p*-tolyl sulfide, 80 percent of 1,4-diphenyl-1,3-butadiene. The same sulfoxide, treated with phenylmagnesium bromide, is said to yield, in addition to phenyl *p*-tolyl sulfide, β,β,β -triphenylethyl *p*-tolyl sulfide.

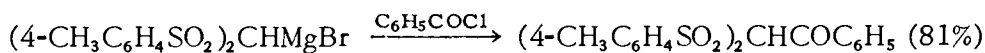
SULFONES

When Hepworth and Clapham (*loc. cit.*⁴⁸) refluxed 5.5 g. of phenyl sulfone with methylmagnesium iodide in toluene solution for eighteen hours they were able to recover 4.0 g. of the sulfone. No phenyl sulfide or sulfonium base was detected.

Because phenyl benzyl sulfone was also recovered, apparently unchanged, after high-temperature treatment with methylmagnesium iodide and hydrolysis of the reaction mixture, Hepworth and Clapham concluded that this sulfone also is unreactive toward Grignard reagents. Unfortunately the reaction was not investigated in the Zerewitinoff apparatus.

Kohler and Potter (*loc. cit.*^{49.1}) found that phenethyl *p*-tolyl sulphone and β,β -diphenylethyl *p*-tolyl sulfone liberate at least one molecular equivalent each of methane when treated with isoamyl ethereal methylmagnesium iodide at 50–75°. Methyl *p*-tolyl sulfone liberates methane from methylmagnesium iodide slowly at room temperature. In the latter case it would appear that there are two replaceable hydrogen atoms, for, when the resultant organometallic intermediate is treated with benzoyl chloride, the product is dibenzoylmethyl *p*-tolyl sulfone.

Kohler and Potter^{49.2} also obtained from bis-(*p*-tolylsulfonyl)methane a bromomagnesium derivative which, when treated with benzoyl chloride, yielded α,α -bis-(*p*-tolylsulfonyl)acetophenone.



Gilman and Webb^{49.3} report that ethyl phenyl sulfone, treated successively with ethylmagnesium bromide and carbon dioxide, yields an acidic gum. Field,^{49.4} treating methyl phenyl sulfone successively with ethyl-

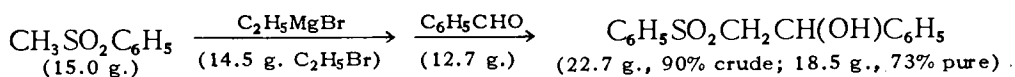
^{49.1} Kohler and Potter, *J. Am. Chem. Soc.*, 57, 1316–21 (1935).

^{49.2} Kohler and Potter, *J. Am. Chem. Soc.*, 58, 2166–30 (1936).

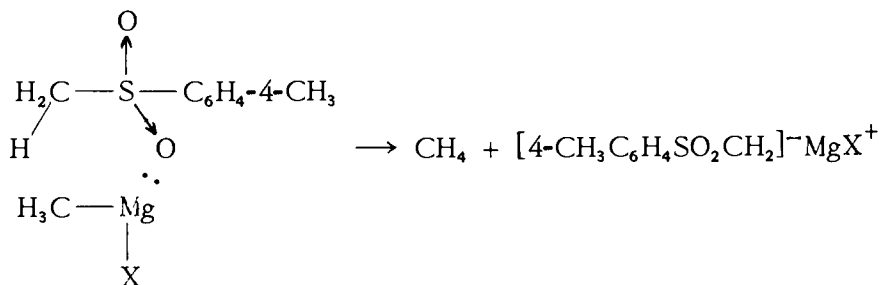
^{49.3} Gilman and Webb, *J. Am. Chem. Soc.*, 71, 4062–6 (1949).

^{49.4} Field, *J. Am. Chem. Soc.*, 74, 3919–21 (1952).

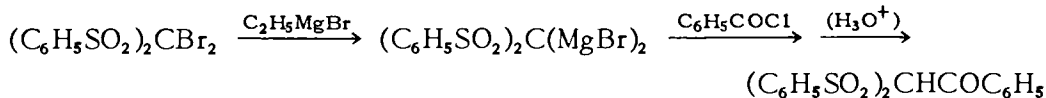
magnesium bromide and benzaldehyde, obtained 1-phenyl-2-phenylsulfonylethanol in good yield.



These hydrogen displacements are strikingly similar to ketone-enolate conversions (*q.v.*), and should probably be formulated similarly.



The analogy is emphasized by the fact that, by a process similar to the reductive enolization of an α -halo ketone (*q.v.*), an α -halo sulfone may be converted to a halomagnesium derivative that behaves like a Grignard reagent. According to Kohler and Tishler,^{49.5} bis(phenylsulfonyl) dibromomethane, treated with ethylmagnesium bromide, yields a di(bromomagnesium) derivative which, however, is only monobenzoyleted by benzoyl chloride.



Ziegler and Connor^{49.6} report that when 34.8 g. of *p*-tolylsulfonylmethyl bromide was treated with 0.15 mole of phenylmagnesium bromide they were able to recover from the reaction mixture, after acid hydrolysis, 15.5 g. (59 percent) of methyl *p*-tolyl sulfone and 18.2 g. (77 percent) of bromobenzene.

α,β -Unsaturated sulfones also undergo 1,4-additions of Grignard reagents, analogous to those of α,β -unsaturated ketones (*q.v.*), to yield enol-like halomagnesium derivatives which behave like Grignard reagents. According to Kohler and Potter (*loc. cit.*^{49.1}), benzylidenemethyl *p*-tolyl sulfone reacts with phenylmagnesium bromide to yield the same bromomagnesium derivative that is obtained upon treatment of β,β -diphenylethyl *p*-tolyl sulfone with ethyl- or phenylmagnesium bromide. Perhaps the absolute identity of the two halomagnesium derivatives should not be taken for granted, however, for analogous pairs of ketonic enolates have been found to yield stereoisomeric derivatives upon acylation^{49.7} or halogenation^{49.8} [see Chapter VI, α -Halo Ketones, Probable Mechanism of

^{49.5} Kohler and Tishler, *J. Am. Chem. Soc.*, 57, 217-24 (1935).

^{49.6} Ziegler and Connor, *J. Am. Chem. Soc.*, 62, 2596-9 (1940).

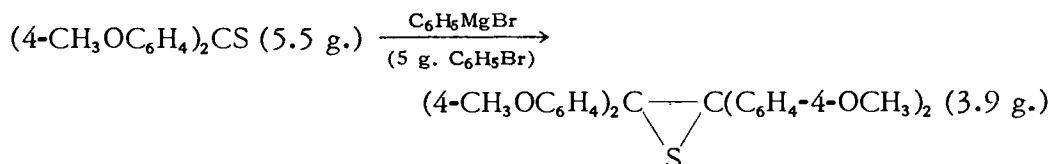
^{49.7} Kohler, Tishler, and Potter, *J. Am. Chem. Soc.*, 57, 2517-21 (1935).

^{49.8} Lutz and Kibler, *J. Am. Chem. Soc.*, 62, 360-72 (1940).

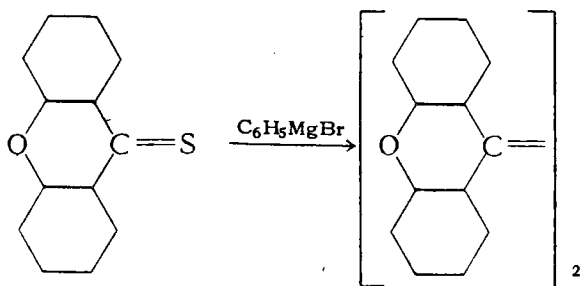
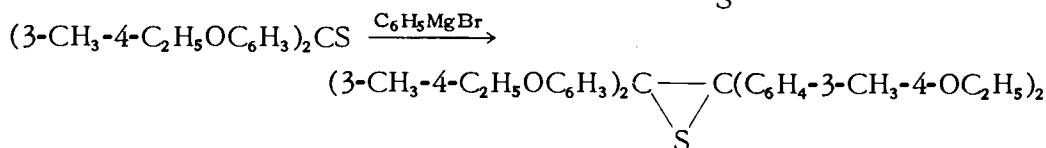
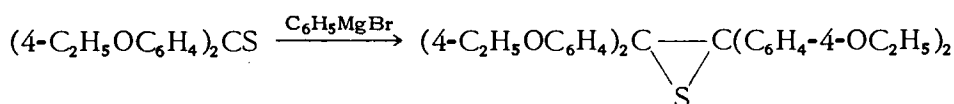
α -Halo Ketone Dehalogenation; Chapter VI, Grignard Reagent Addition to Conjugated Carbonyl Systems, Probable Mechanism of 1,4-Addition].

THIOKETONES (THIONES)

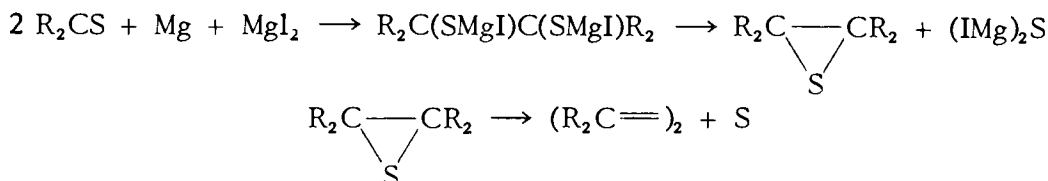
Schönberg, *et al.*⁵⁰ have studied a few thioketone-Grignard reagent reactions. In general the products are ethylene sulfides (thioepoxides) or the corresponding ethylene derivatives, which are probably formed by loss of sulfur by the thermolabile sulfides.



With the same thioketone, "good yields" of sulfide were obtained with 2-CH₃OC₆H₄MgBr, 1-C₁₀H₇MgBr, and C₆H₅MgI; a poor yield with C₂H₅MgBr. Other reactions reported are:



Apparently these are essentially radical reactions, for Schönberg and Schütz⁵¹ have found that treatment of a thioketone with magnesium-magnesium iodide yields the same products as treatment with a Grignard reagent. They explain the reaction as follows:



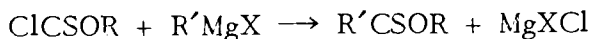
The desirability of the prosecution of analogous studies with *filtered* Grignard reagents prepared from sublimed magnesium is indicated.

⁵⁰Schönberg, *Ber.*, 58B, 1793-1801 (1925); Schönberg, Rosenbach, and Schütz, *Ann.*, 454, 37-46 (1927).

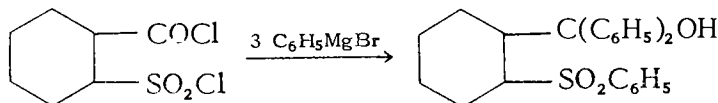
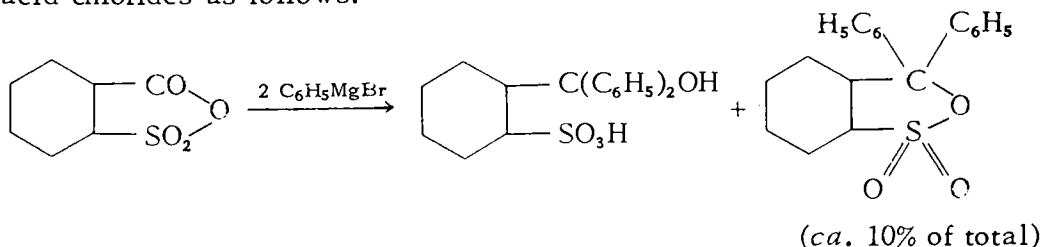
⁵¹Schönberg and Schütz, *Ber.*, 60B, 2351-3 (1927).

MISCELLANEOUS UNCLASSIFIED SULFUR COMPOUNDS

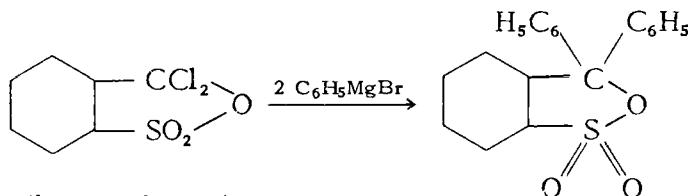
Delepine⁵² has investigated the reactions of several Grignard reagents with several thiochloroformic esters. According to his reports such reactions take the course:



Cobb⁵³ has reported on the reactions of phenylmagnesium bromide with *o*-sulfobenzoic anhydride and the corresponding high- and low-melting acid chlorides as follows:

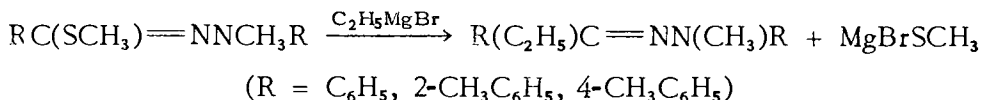


(h.-m. chloride)

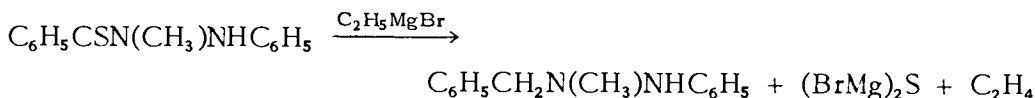


(l.-m. chloride)

According to Wuyts and Lacourt,⁵⁴ when *S*-methylated thiohydrazides are treated with ethylmagnesium bromide, the methylmercapto group is replaced by an ethyl group.



The corresponding *N*-methylated thiohydrazides are reduced by ethylmagnesium bromide.



Gilman and Vernon⁵⁵ observed no reaction (other than "active" hydrogen replacement) of *p*-toluenesulfonamide with excess phenylmagnesium

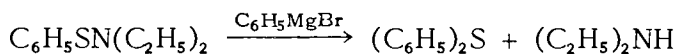
⁵²Delepine, *Compt. rend.*, 150, 1607-8 (1910); 153, 279-82 (1911); *Chem. Zentr.*, 1910,II, 794; 1911,II, 1213.

⁵³Cobb, *Am. Chem. J.*, 35, 486-508 (1906); Cobb and Fuller, *ibid.*, 45, 605-11 (1911).

⁵⁴Wuyts and Lacourt, *Bull. soc. chim. Belg.*, 44, 395-410 (1935).

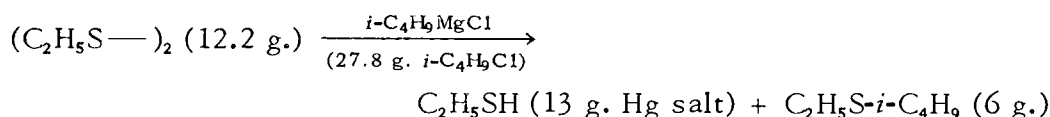
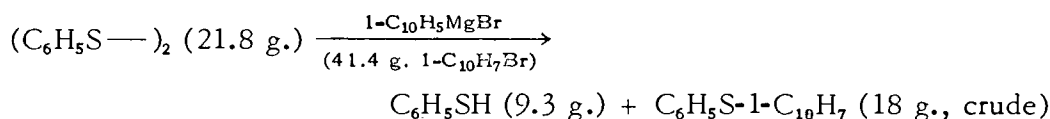
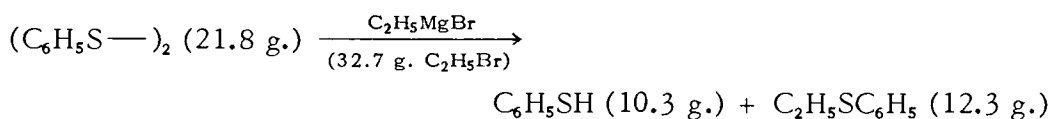
⁵⁵Gilman and Vernon, *Rec. trav. chim.*, 48, 745-7 (1929).

bromide in boiling ether. In boiling anisole some tar was formed, but 62.5 percent of the amide was recovered. The corresponding imide $[(4\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2)_2\text{NH}]$ is similarly inert toward phenylmagnesium bromide in boiling ether or toluene, as is benzenesulfinanilide. *N,N*-Diethylbenzenesulfenamide slowly undergoes cleavage when refluxed at 70° with phenylmagnesium bromide in ether-toluene solution.

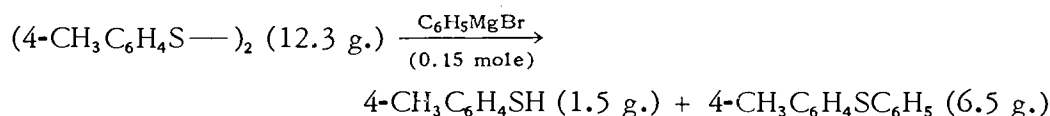
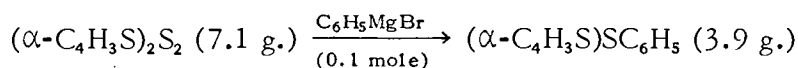


The reactions of saccharin and *N*-alkylated saccharins are reported in Chapter XII on Amides, etc. (*q.v.*).

Wuyts⁵⁶ reports that disulfides undergo Grignard reagent cleavage.



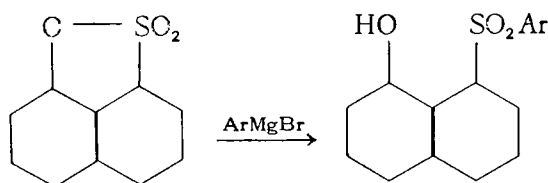
Other examples of disulfide cleavage are reported by Burton and Davy.⁵⁷



Reactions of thionylaniline are reported in Chapter XIX on Miscellaneous Nitrogen Compounds (*q.v.*).

4,4,5,5-Tetraphenyltrimethylene-1,3-disulfide is inert toward phenylmagnesium bromide, according to Schönberg *et al.*⁵⁸

According to Mustafa and Gad,⁵⁹ naphthasultone reacts with phenyl- and 1-naphthylmagnesium bromides in boiling ether-benzene solution to form hydroxylated sulfones.



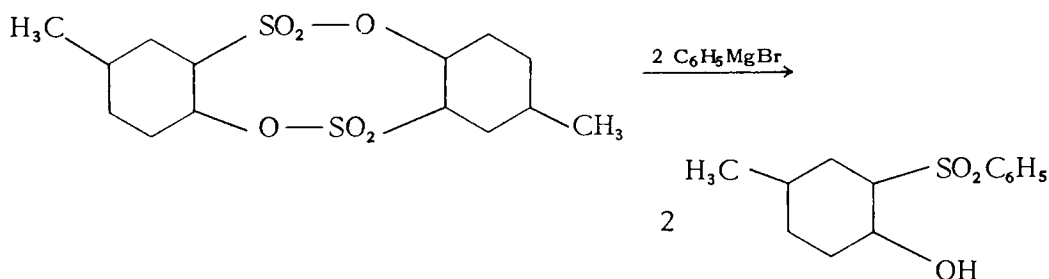
⁵⁶ Wuyts, *Bull. soc. chim.*, [3], 35, 166-9 (1906).

⁵⁷ Burton and Davy, *J. Chem. Soc.*, 1948, 325-7, 528-9.

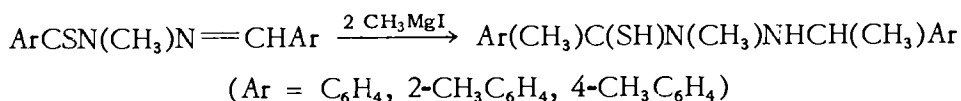
⁵⁸ Schönberg, Kaltschmitt, and Schulten, *Ber.*, 66B, 245-50 (1933).

⁵⁹ Mustafa and Gad, *J. Chem. Soc.*, 1949, 384-7.

The sulfonylidene ring is similarly opened by phenylmagnesium bromide (Mustafa and Gad, *loc. cit.*⁵⁹).



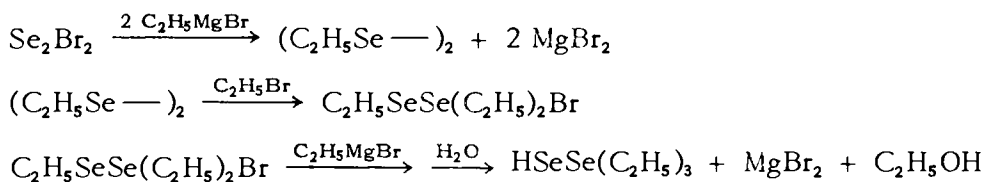
The reactions of various thioacylated hydrazines with methylmagnesium iodide are reported by Wuyts and Lacourt⁶⁰ to take the following course:



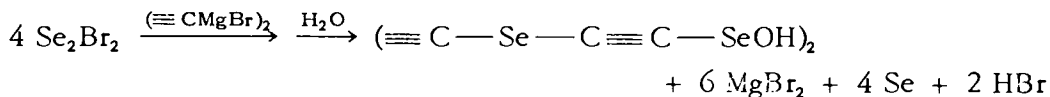
According to the same authors,⁶⁰ several derivatives of 2,3-dihydro-1,3,4-thiadiazole were recovered completely unchanged after treatment with five molecular equivalents of methylmagnesium iodide.

SELENIUM COMPOUNDS

Pieroni and Coli⁶¹ conducted a Barbier-type reaction with magnesium, ethyl bromide and selenium monobromide. Their description of the reaction is as follows:



They also treated selenium bromide with the dihalomagnesium derivative of acetylene:



Pieroni and Balduzzi⁶² treated phenylmagnesium bromide with selenium monobromide and obtained phenyl diselenide which, upon heating, readily loses selenium to form the selenide. They also report that *m*-

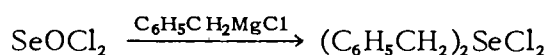
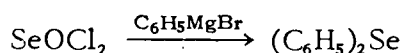
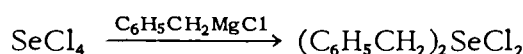
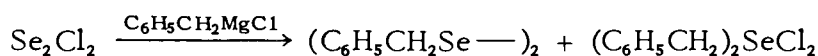
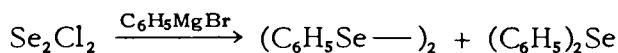
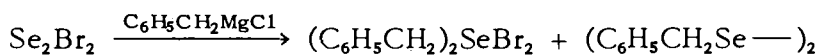
⁶⁰ Wuyts and Lacourt, *Bull. soc. chim. Belg.*, 45, 445-53 (1936).

⁶¹ Pieroni and Coli, *Gazz. chim. ital.*, 44,II, 349-53 (1914); *Chem. Zentr.*, 1915,I, 730.

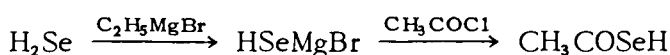
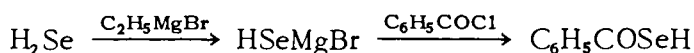
⁶² Pieroni and Balduzzi, *Gazz. chim. ital.*, 45,II, 106-11 (1915); *Chem. Zentr.*, 1915,II, 1134.

aminophenylmagnesium bromide [*sic*] reacts with selenium monobromide to form the selenide.

Strecker and Willing⁶³ have reported reactions of Grignard reagents with selenium monobromide, selenium monochloride, selenium tetrachloride, and selenyl chloride, as follows:

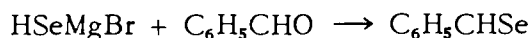
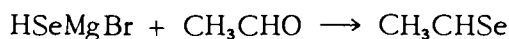
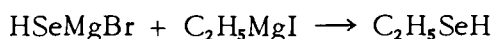
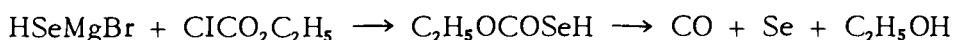


Mingioia⁶⁴ has prepared selenocarboxylic acids by treating hydrogen selenide successively with a Grignard reagent and a carbonyl chloride.



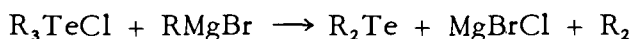
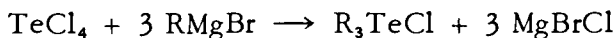
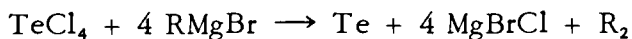
The selenium of such acids is said to be readily replaceable by atmospheric oxygen.

Other reactions of bromomagnesium hydrogen selenide reported by Mingioia (*loc. cit.*^{64b}) are:



TELLURIUM COMPOUNDS

Tellurium compounds have been investigated chiefly by Lederer. A summary of available data is recorded in Table XXI-VIII. The reactions suggested by Lederer to account for the observed products of the tetrahalides are:



⁶³ Strecker and Willing, *Ber.*, 48, 196-206 (1915).

⁶⁴ Mingioia, (a) *Gazz. chim. ital.*, 56, 835-9 (1926); *Chem. Zentr.*, 1927, I, 1953; (b) *Gazz. chim. ital.*, 58, 667-73 (1928); *Chem. Zentr.*, 1929, I, 634.

TABLE XXI-VIII

REACTIONS OF GRIGNARD REAGENTS WITH TELLURIUM COMPOUNDS

Te Comp'd	RMgX	Product(s)	Ref.
TeCl ₄	C ₆ H ₅ MgBr (5 equiv.)	C ₆ H ₅ Cl + (C ₆ H ₅ —) ₂ + (C ₆ H ₅) ₂ Te + (C ₆ H ₅) ₃ TeX*	1,2
TeCl ₄	2-CH ₃ C ₆ H ₄ MgBr	(2-CH ₃ C ₆ H ₄) ₃ TeX*	2
TeCl ₄	3-CH ₃ C ₆ H ₄ MgBr	(3-CH ₃ C ₆ H ₄) ₃ TeX* (ca. 26%)	7
TeCl ₄	4-CH ₃ C ₆ H ₄ MgBr	(4-CH ₃ C ₆ H ₄) ₃ TeX*	2
TeCl ₄	2-CH ₃ OC ₆ H ₄ MgBr	(2-CH ₃ OC ₆ H ₄) ₃ TeX* (ca. 15-25%)	18
TeCl ₄	4-CH ₃ OC ₆ H ₄ MgBr	(4-CH ₃ OC ₆ H ₄) ₃ TeX*	7
TeCl ₄	2,4-(CH ₃) ₂ C ₆ H ₃ MgBr	[2,4-(CH ₃) ₂ C ₆ H ₃] ₃ TeX*	7
TeCl ₄	2,5-(CH ₃) ₂ C ₆ H ₃ MgBr	[2,5-(CH ₃) ₂ C ₆ H ₃] ₃ TeX*	7
TeCl ₄	2-C ₂ H ₅ OC ₆ H ₄ MgBr	(2-C ₂ H ₅ OC ₆ H ₄) ₃ TeX* (ca. 28%)	10
TeCl ₄	4-C ₂ H ₅ OC ₆ H ₄ MgBr	(4-C ₂ H ₅ OC ₆ H ₄) ₃ TeX* (ca. 29%)	10
TeBr ₂	2-Thienyl-MgBr	(2-C ₄ H ₃ S) ₂ Te [†] (ca. 62%)	15
TeBr ₂	4-BrC ₆ H ₄ MgBr	(4-BrC ₆ H ₄) ₂ Te [†] (ca. 27%) + 4-BrC ₆ H ₄ TeC ₆ H ₄ C ₆ H ₄ - 4Br [‡] (ca. 24%)	9
TeBr ₂	4-ClC ₆ H ₄ MgBr	(4-ClC ₆ H ₄) ₂ Te [†] (ca. 54%)	9
TeBr ₂	3-CH ₃ C ₆ H ₄ MgBr	(3-CH ₃ C ₆ H ₄ Te—) ₂	5
TeBr ₂	3-CH ₃ OC ₆ H ₄ MgI	(3-CH ₃ OC ₆ H ₄) ₂ Te [†] (ca. 48%)	14
TeBr ₂	4-CH ₃ OC ₆ H ₄ MgBr	(4-CH ₃ OC ₆ H ₄) ₂ Te [†] (ca. 62%)	6
TeBr ₂	2,4-(CH ₃) ₂ C ₆ H ₃ MgBr	[2,4-(CH ₃) ₂ C ₆ H ₃] ₂ Te [†] (ca. 53%)	3
TeBr ₂	2,5-(CH ₃) ₂ C ₆ H ₃ MgBr	[2,5-(CH ₃) ₂ C ₆ H ₃] ₂ Te (ca. 52%)	3
TeBr ₂	4-C ₂ H ₅ OC ₆ H ₄ MgBr	(4-C ₂ H ₅ OC ₆ H ₄) ₂ Te [†] (ca. 39%)	13
TeBr ₂	2,4,6-(CH ₃) ₃ C ₆ H ₂ MgBr	[2,4,6-(CH ₃) ₃ C ₆ H ₂] ₂ Te	4
TeBr ₂	1-C ₁₀ H ₇ MgBr	(1-C ₁₀ H ₇) ₂ Te [†] (ca. 62%)	12
TeBr ₂	2-C ₂ H ₅ OC ₆ H ₄ MgBr	(2-C ₂ H ₅ OC ₆ H ₄) ₂ Te [†] (ca. 34%)	11
(2-Thienyl) ₂ TeBr ₂	2-Thienyl-MgBr	(2-C ₄ H ₃ S) ₃ TeBr	15
(C ₆ H ₅) ₂ TeCl	R'MgBr	R'(C ₆ H ₅) ₂ TeX [§]	16
(C ₆ H ₅) ₂ TeBr ₂	2-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ (2-CH ₃ C ₆ H ₄)Te [¶] (ca. 18%)	17

* Product isolated after treatment with KI, as R₃TeI.† Product isolated, after treatment with Br₂, as R₂TeBr₂.‡ Product isolated, after treatment with I₂, as R₂TeI₂.§ Product isolated, after treatment with KI, as R'R₂TeI; R' = C₆H₅, 2-CH₃C₆H₄, 3-CH₃C₆H₄, 4-CH₃C₆H₄, 4-CH₃OC₆H₄, 2,4-(CH₃)₂C₆H₃, 2,5-(CH₃)₂C₆H₃, 3,4-(CH₃)₂C₆H₃, 2,4,6-(CH₃)₃C₆H₂, 1-C₁₀H₇.¶ Product isolated, after treatment with Br₂, as RR'TeBr₂.

TABLE XXI-VIII (Continued)

Te Comp'd	RMgX	Product(s)	Ref.
$C_6H_5(2-CH_3C_6H_4)TeBr$	CH_3MgI	$C_6H_5(2-CH_3C_6H_4)Te$ (77%)	17
$(3-CH_3C_6H_4)_2TeBr_2$	CH_3MgI	$(3-CH_3C_6H_4)_2Te$ (90%)	5
$(4-CH_3C_6H_4)_2TeCl_2$	C_6H_5MgBr	$C_6H_5(4-CH_3C_6H_4)_2TeX^*$ (75%)	8
$(4-CH_3C_6H_4)_2TeBr_2$	C_6H_5MgBr	$C_6H_5(4-CH_3C_6H_4)Te^\dagger$ (ca. 78%)	8
$[2,4-(CH_3)_2C_6H_4]_2TeBr_2$	CH_3MgI	$[2,4-(CH_3)_2C_6H_4]_2Te$ (65%)	3
$(4-C_2H_5OC_6H_4)_2TeI_2$	CH_3MgI	$(4-C_2H_5OC_6H_4)_2Te$	13
$(1-C_{10}H_7)_2TeBr_2$	C_2H_5MgI	$(1-C_{10}H_7)_2Te$	12

* Product isolated, after treatment with KI, as $R'R_2TeI$.

† Product isolated, after treatment with Br_2 , as $RR'TeBr_2$.

REFERENCES FOR TABLE XXI-VIII

- (1) Lederer, *Compt. rend.*, 151, 611-2 (1911).
- (2) Lederer, *Ber.*, 44, 2287-92 (1911).
- (3) Lederer, *Ber.*, 49, 334-44 (1916).
- (4) Lederer, *Ber.*, 49, 345-9 (1916).
- (5) Lederer, *Ber.*, 49, 1071-6 (1916).
- (6) Lederer, *Ber.*, 49, 1076-82 (1916).
- (7) Lederer, *Ber.*, 49, 1385-9 (1916).
- (8) Lederer, *Ber.*, 49, 1615-22 (1916).
- (9) Lederer, *Ber.*, 49, 2002-5 (1916).
- (10) Lederer, *Ber.*, 49, 2529-31 (1916).
- (11) Lederer, *Ber.*, 49, 2532-8 (1916).
- (12) Lederer, *Ber.*, 49, 2663-6 (1916).
- (13) Lederer, *Ber.*, 50, 238-43 (1917).
- (14) Lederer, *Ber.*, 52B, 1989-92 (1919).
- (15) Krause and Renwanz, *Ber.*, 62B, 1710-6 (1929).
- (16) Lederer, *Ber.*, 53B, 1430-45 (1920).
- (17) Lederer, *Ber.*, 53B, 1674-80 (1920).
- (18) Lederer, *Ber.*, 53B, 2342-6 (1920).

CHAPTER XXII

Reactions of Grignard Reagents with Silicon Compounds

There have been numerous general reviews of the chemistry of organosilicon compounds, most of which include some discussion of the Grignard reactions. Two of the more comprehensive and more readily accessible surveys are those of Rochow¹ and of Burkhard *et al.*² Both contain references to earlier reviews.

The Grignard reactions of silicon compounds reported are chiefly those of the halides and esters. It is now generally recognized that the silicon analogs of the ketones do not exist and that the silicone reactions reported by Kipping and Hackford³ must be those of compounds of the type $[\text{—RR'SiO—}]_x$. Similarly the supposed orthosiliconic acids are now known to be non-isolable; if they exist at all they immediately undergo dehydration-condensation to form "polymers." The dihydroxydialkylsilicanes behave similarly, but the dihydroxydiarylsilicanes appear to be reasonably stable.

SILICON HALIDES

Unlike carbon tetrachloride, silicon tetrachloride is capable of reacting successively with four molecules of Grignard reagent. However, the relative reactivities of the four halides (SiCl_4 , RSiCl_3 , R_2SiCl_2 , R_3SiCl) do not correspond to the relative amounts of chlorine present. Fouss⁴ has subjected the problem of successive substitution in compounds of the type AX_4 to mathematical analysis. On the basis of Kipping's⁵ figures for the products of the reaction of one molecular equivalent of silicon tetrachloride with two and a quarter molecular equivalents of phenylmagnesium bromide (trichlorophenylsilane, 14 percent; dichlorodiphenylsilane, 44 percent; chlorotriphenylsilane, 5 percent), Fouss concludes that trichlorophenylsilane is materially more reactive than either silicon tetrachloride or dichlorodiphenylsilane. Whether for steric or other reasons, the fourth halogen atom appears to be the most difficultly

¹Rochow, "An Introduction to the Chemistry of the Silicones," John Wiley & Sons, Inc., New York, x + 137 pp, 1946.

²Burkhard, Rochow, Booth, and Hartt, *Chem. Revs.*, 41, 97-149 (1947).

³Kipping and Hackford, *J. Chem. Soc.*, 99, 138-45 (1911).

⁴Fouss, *J. Am. Chem. Soc.*, 65, 2406-8 (1943).

⁵Kipping, *J. Chem. Soc.*, 101, 2108-25 (1912).

replaceable of all. Indeed, Medoks and Kotelkov⁶ report that, even in the presence of an excess of Grignard reagent, the reaction of silicon tetrafluoride with phenylmagnesium bromide does not proceed at room temperature beyond the formation of fluorotriphenylsilicane.

Qualitative examination of the available data indicates that in general the silicon halides are more reactive toward alkyl than toward aryl Grignard reagents, which would suggest that the order of reactivity for Grignard reagents is the same as that established by Kharasch and Weinhouse⁷ for the ketones (in which reactivity increases as the "electronegativity" of the organic radical of the Grignard reagent decreases). If this be true, however, steric factors must also play a significant, and sometimes a critical, part, for Sommer *et al.*⁸ report that when chlorotriethylsilicane is treated with an equimolecular mixture of methyl- and ethylmagnesium bromides the only condensation product detectable is methyltriethylsilicane.⁹

Like silicon tetrachloride, silicochloroform is subject to successive chlorine replacements upon reaction with Grignard reagents.

According to Schumb and Saffer¹⁰ hexachlorodisilicoethane reacts with alkyl or aryl Grignard reagents to form hexaalkyl- or hexaaryldisilicoethanes, respectively. Silicon-to-silicon bond cleavage is also reported (Schumb and Saffer, *loc. cit.*;¹⁰ Schwarz and Sexauer¹¹). Octachlorotrisilicopropane apparently yields cleavage products only with phenylmagnesium bromide (Schumb and Saffer, *loc. cit.*¹⁰).

Hexachlorosilicyl oxide is reported as reacting similarly to hexachlorodisilicoethane (Schumb and Saffer, *loc. cit.*;¹⁰ Emeléus and Payne¹².)

SILICON ESTERS

Tetraethoxysilicane and the orthosiliconates react with Grignard reagents in a manner similar to that of the corresponding halides, though somewhat less readily.

Data concerning representative reactions are assembled in Table XXII-I. No attempt has been made to include an exhaustive resumé of the patent literature. Reactions leading to product mixtures of unknown composition have been, for the most part, intentionally omitted.

⁶Medoks and Kotelkov, *J. Gen. Chem.* (U.S.S.R.), 7, 2007-8 (1937); *Chem. Abstr.*, 32, 531 (1938).

⁷Kharasch and Weinhouse, *J. Org. Chem.*, 1, 209-30 (1936).

⁸Sommer, Kerr, and Whitmore, *J. Am. Chem. Soc.*, 70, 434-5 (1948).

⁹The methyl radical is somewhat more "electronegative" than the ethyl radical. For a discussion of the relative "electronegativities" of organic radicals see: Kharasch and Reinmuth, *J. Chem. Education*, 5, 404-18; 8, 1703-48 (1931); Kharasch, Reinmuth, and Mayo, *ibid.*, 11, 82-96 (1934); 13, 7-19 (1936).

¹⁰Schumb and Saffer, *J. Am. Chem. Soc.*, 61, 363-6 (1939).

¹¹Schwarz and Sexauer, *Ber.*, 59B, 333-7 (1926).

¹²Emeléus and Payne, *J. Chem. Soc.*, 1947, 1590-2.

SOME ILLUSTRATIVE PREPARATIONS

Ethyltrichlorosilane from silicon tetrachloride (Andrianov¹³).—Magnesium (12 g.) was treated with several drops of tetraëthoxysilane and then dropwise with 40 g. of ethyl bromide, after which an additional 22 g. of ethyl bromide in benzene solution was added, and the mixture was re-refluxed for an hour and a half (yield 93.3% C_2H_5MgBr). To the Grignard solution was slowly added 85 g. of silicon tetrachloride in 100 ml. of benzene, and the mixture was refluxed for three to four hours (yield 65 g., 80%, $C_2H_5SiCl_3$).

Dichlorodiethylsilane from silicon tetrachloride (Andrianov¹³).—The preparation of the dialkyl derivative was carried out in the manner described for the monoalkyl derivative save that the quantity of silicon tetrachloride was halved [yield 70.3%, $(C_2H_5)_2SiCl_2$].

*Fluorotri-*n*-amylsilane from silicon tetrafluoride* (Gierut et al.¹⁴).—One mole of *n*-amylmagnesium chloride was prepared in a 2-liter, three-necked flask equipped with a reflux condenser, a stirrer, and an inlet tube extending to the bottom of the flask. Silicon tetrafluoride was passed into the well-stirred Grignard solution until a short time after the system had separated into a clear upper layer and a gray, turbid lower layer. The layers were separated; the lower, ether-insoluble layer was thoroughly washed with ether, and the washings were added to the upper layer. Ether was distilled from the ethereal layer and the residue was fractionally distilled. The principal fraction (b.p. $267^\circ/745$ mm.) was fluorotri-*n*-amylsilane (50 g., 57.6%).

Tetraëthylsilane from silicon tetrachloride (Sugden and Wilkins¹⁵).—To 128 g. of magnesium in 690 ml. of dry ether, 10 g. of ethyl bromide and a crystal of iodine were added. When vigorous reaction set in the remainder of the ethyl bromide (440 g. in all), diluted with 200 ml. of benzene, was added slowly. Finally a further 500 ml. of benzene, warmed to 40° , was added, and the Grignard solution was decanted from excess magnesium. To this Grignard solution was added 68 g. of silicon tetrachloride, and the mixture was heated on the water-bath for twelve to fifteen hours. After decomposition with dilute acid and removal of the solvents from the benzene-ether layer, 45 g. of crude product was obtained. From this the silicols were removed by repeated shaking with concentrated sulfuric acid. The residue (20 g.) proved upon distillation to be nearly pure tetraëthylsilane.

Tetraphenylsilane from silicon tetrachloride (Schumb and Saffer¹⁶).—In an experiment employing the Barbier modification of the Grignard reac-

¹³Andrianov, *J. Gen. Chem.*, (U.S.S.R.), 16, 487-92 (1946); *Chem. Abstr.*, 41, 701 (1947).

¹⁴Gierut, Sowa, and Nieuwland, *J. Am. Chem. Soc.*, 58, 897-8 (1936).

¹⁵Sugden and Wilkins, *J. Chem. Soc.*, 1931, 126-8.

¹⁶Schumb and Saffer, *J. Am. Chem. Soc.*, 61, 363-6 (1939).

tion, 6 g. of silicon tetrachloride and 30 g. of bromobenzene in 100 ml. of anhydrous ether were allowed to drop on magnesium turnings activated with a crystal of iodine. The vigorous ensuing reaction ultimately yielded 8.8 g. (75%) of tetraphenylsilane.

Triethylsilane from trichlorosilane (Whitmore et al.¹⁷).—Ethylmagnesium bromide (12.6 moles) was prepared in a 5-liter three-necked flask, fitted with an efficient stirrer, a dropping funnel, and a large bulb condenser, each connected with a Dry Ice-acetone trap. A cold solution of 406.5 g. (3 moles) of trichlorosilane in 1200 ml. of anhydrous ethyl ether was added, with cooling and vigorous stirring during a period of six hours. The mixture was stirred at room temperature for eight hours and then heated to reflux for five hours. Ether was removed from the reaction mixture through a 20-plate column, and the residue was heated on a steam-bath for ten hours. With cooling, the solid residue was hydrolyzed with 180 ml. of water, followed by 372 ml. of concentrated hydrochloric acid. The aqueous layer was separated and extracted twice with 500-ml. portions of ether. The ether extracts and product were combined, washed with water, and then dried over 150 g. of anhydrous potassium carbonate. Fractional distillation of the product through a 20-plate column yielded 270.3 g. (77.5%) of triethylsilane.

Hexaëthyldisiloxane from ethyl orthosilicate (Di Giorgio et al.¹⁸).—In a 12-liter three-necked flask, fitted with a mercury-sealed stirrer, reflux condenser, and dropping funnel, there was prepared 22 equivalents of ethylmagnesium bromide in 10 liters of ether. The flask was cooled with tap water, and 1450 g. (7.0 moles) of ethyl orthosilicate was added during one hour. After one hour stirring at room temperature the ether was distilled, and the residue was heated on a steam-bath for twelve hours. The ether was then returned to the flask, and hydrolysis was effected with ice, water, and acid. After separation of the ether layer, the ether was distilled from the product; a small amount of ethanol was also removed by distillation. The product was dissolved, with cooling, in 1.5 liter of concentrated sulfuric acid. This was then added to 6 liters of cold water, and the organic layer was separated, dried with calcium chloride, and fractionated. Hexaëthyldisiloxane (573 g., 2.3 moles) was thus obtained in 66% yield.

¹⁷Whitmore, Pietrusza, and Sommer, *J. Am. Chem. Soc.*, 69, 2108-10 (1947).

¹⁸Di Giorgio, Strong, Sommer, and Whitmore, *J. Am. Chem. Soc.*, 68, 1380 (1946).

TABLE XXII-I
REACTIONS OF GRIGNARD REAGENTS WITH SILICON COMPOUNDS
(Polymers are listed under the empirical formulae of the monomers.)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
SiF₄			
SiF ₄	C ₂ H ₅ MgBr	(C ₂ H ₅) ₃ SiF (45%); (C ₂ H ₅) ₄ Si (<i>ca.</i> 45%)	53,54
SiF ₄	<i>n</i> -C ₃ H ₇ MgBr	(<i>n</i> -C ₃ H ₇) ₃ SiF (62%)	53
SiF ₄	<i>n</i> -C ₄ H ₉ MgCl (1 mole)	(<i>n</i> -C ₄ H ₉) ₃ SiF (51 g., 70%)	53
SiF ₄	<i>n</i> -C ₄ H ₉ MgBr (1 mole)	(<i>n</i> -C ₄ H ₉) ₃ SiF (46 g., 63.2%)	53
SiF ₄	<i>n</i> -C ₅ H ₁₁ MgCl (1 mole)	(<i>n</i> -C ₅ H ₁₁) ₃ SiF (50 g., 57.6%)	53
SiF ₄	C ₆ H ₅ MgBr (<i>excess</i>)	(C ₆ H ₅) ₃ SiF	55
SiF ₄	C ₆ H ₅ CH ₂ MgCl	(C ₆ H ₅ CH ₂) ₃ SiF; (C ₆ H ₅ CH ₂) ₄ Si	56
SiF₆Na₂			
Na ₂ SiF ₆ (30 g.)	C ₂ H ₅ MgBr (144 g. C ₂ H ₅ Br)	(C ₂ H ₅) ₄ Si (23%)	57
Na ₂ SiF ₆ (3.8 g.)	C ₆ H ₅ MgBr (26 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₄ Si (33.9%)	42
Na ₂ SiF ₆ (3.76 g.)	C ₆ H ₅ CH ₂ MgCl (10.22 g. C ₆ H ₅ CH ₂ Cl)	(C ₆ H ₅ CH ₂) ₄ Si (20.7%)	58,42
SiCl₄			
SiCl ₄ (3.97 moles)	CH ₃ MgCl (1.6 l., 3.1 M)	CH ₃ SiCl ₃ (115 g. crude; 60 g. pure)	2
SiCl ₄ (212 ml.)	CH ₃ MgCl (2.05 l., 2.3 M)	(CH ₃) ₂ SiCl ₂ (26.5 g.)	2
SiCl ₄	CH ₃ MgBr (9.9 moles)	CH ₃ SiCl ₃ (564 g., 38%)	3
SiCl ₄ (1 l.)	CH ₃ MgX (2 moles)	CH ₃ SiCl ₃ ; (CH ₃) ₂ SiCl ₂	4,5
SiCl ₄ (1 mole)	CH ₃ MgBr (3 moles)	(CH ₃) ₂ SiCl ₂ ; (CH ₃) ₃ SiCl	6,7
SiCl ₄ (50 g.)	CH ₃ MgBr (30 g. Mg)	(CH ₃) ₄ Si (<i>ca.</i> 13.2 g.)	8
SiCl ₄ (4.4 moles)	CH ₃ MgBr (19.1 moles)	(CH ₃) ₄ Si (63%)	9
SiCl ₄	CH ₃ MgBr	(CH ₃) ₄ Si	10,10.1
SiCl ₄	CH ₃ MgI	(CH ₃) ₄ Si	11
SiCl ₄ (30 g.)	HC≡CMgBr	After hydrolysis: [(HC≡C) ₃ Si] ₂ O (3-5 g.)	12

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
SiCl₄ (cont.)			
SiCl ₄ (1.0 equiv.)	C ₂ H ₅ MgCl (2.25 equiv.)	(C ₂ H ₅) ₄ Si (0.0 part); (C ₂ H ₅) ₃ SiCl (0.26 part); (C ₂ H ₅) ₂ SiCl ₂ (0.1 part); C ₂ H ₅ SiCl ₃ (0.5 part)*	126
SiCl ₄ (1.0 equiv.)	C ₂ H ₅ MgCl (3.6 equiv.)	(C ₂ H ₅) ₄ Si (0.24 part); (C ₂ H ₅) ₃ SiCl (1.00 part); (C ₂ H ₅) ₂ SiCl ₂ (0.89 part); C ₂ H ₅ SiCl ₃ (0.19 part) [†]	126
SiCl ₄	C ₂ H ₅ MgCl	(C ₂ H ₅) ₄ Si (70–80%)	17
SiCl ₄ (50 g.)	C ₂ H ₅ MgBr (1.2 equiv.)	C ₂ H ₅ SiCl ₃ (30–35 g., crude)	13,3,8,14
SiCl ₄ (1 equiv.)	C ₂ H ₅ MgBr (2 equiv. Mg)	C ₂ H ₅ SiCl ₃ ; (C ₂ H ₅) ₂ SiCl ₂ ("poor yields")	15
SiCl ₄ (85 g.)	C ₂ H ₅ MgBr (ca. 1 equiv.)	C ₂ H ₅ SiCl ₃ (65 g.)	16
SiCl ₄	C ₂ H ₅ MgBr (ca. 2 equiv.)	(C ₂ H ₅) ₂ SiCl ₂ (70.3%)	16,64
SiCl ₄ (160 g.)	C ₂ H ₅ MgBr (2.5 equiv.)	C ₂ H ₅ SiCl ₃ ; (C ₂ H ₅) ₂ SiCl ₂ (ca. 18 g.); (C ₂ H ₅) ₃ SiCl	15,8,18
SiCl ₄ (68 g.)	C ₂ H ₅ MgBr (440 g. C ₂ H ₅ Br)	(C ₂ H ₅) ₄ Si (ca. 20 g.)	19,8,17, 20
SiCl ₄	C ₂ H ₅ MgI	C ₂ H ₅ SiCl ₃ ; (C ₂ H ₅) ₂ SiCl ₂ ; (C ₂ H ₅) ₃ SiCl; (C ₂ H ₅) ₄ Si	13a
SiCl ₄	H ₂ C=CHCH ₂ Cl + Mg	(H ₂ C=CHCH ₂) ₄ Si (ca. 90%)	21
SiCl ₄ (100 g.)	<i>n</i> -C ₃ H ₇ MgBr (1.25 equiv. Mg)	<i>n</i> -C ₃ H ₇ SiCl ₃ (ca. 30 g.)	22,8,23, 24,25
SiCl ₄	<i>n</i> -C ₃ H ₇ MgX	(<i>n</i> -C ₃ H ₇) ₄ Si	19
SiCl ₄ (4 moles)	<i>i</i> -C ₃ H ₇ MgCl	<i>i</i> -C ₃ H ₇ SiCl ₃ (30–50%)	26
SiCl ₄ (0.8 g.)	2-Thienyl-MgI (10 g. C ₄ H ₃ SI)	(α -C ₄ H ₃ S) ₄ Si (50%)	27
SiCl ₄ (125 g.)	<i>n</i> -C ₄ H ₉ MgBr (20.5 g. Mg)	<i>n</i> -C ₄ H ₉ SiCl ₃ (86.5 g., crude)	8,28
SiCl ₄	<i>n</i> -C ₄ H ₉ MgX	(<i>n</i> -C ₄ H ₉) ₂ SiCl ₂	7

* The aggregate product contained 34% Si, as compared with 17.9% Si for (C₂H₅)₂SiCl₂.

[†] The aggregate product contained 24% Si, as compared with 18.6% Si for (C₂H₅)₃SiCl.

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
SiCl₄ (cont.)			
SiCl ₄ (0.103 mole)	<i>n</i> -C ₄ H ₉ MgBr (1.05 mole C ₄ H ₉ Br)	(<i>n</i> -C ₄ H ₉) ₄ Si (44.5%)	20
SiCl ₄ (116 g.)	<i>i</i> -C ₄ H ₉ MgBr (16.6 g. C ₄ H ₉ Br)	<i>i</i> -C ₄ H ₉ SiCl ₃ (ca. 79.5 g.)	8
SiCl ₄	<i>i</i> -C ₄ H ₉ MgCl (ca. 1 equiv.)	<i>i</i> -C ₄ H ₉ SiCl ₃	16
SiCl ₄	<i>i</i> -C ₄ H ₉ MgCl (ca. 2 equiv.)	(<i>i</i> -C ₄ H ₉) ₂ SiCl ₂	16
SiCl ₄ (20 g.)	H ₂ C(CH ₂ CH ₂ MgBr) ₂ (30 g. C ₄ H ₈ Br ₂)	(CH ₂) ₅ SiCl ₂ (ca. 59%)	29
SiCl ₄	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₅ H ₁₁ SiCl ₃ (52%)	31
SiCl ₄ (113.5 g.)	<i>i</i> -C ₅ H ₁₁ MgBr (100.7 g. C ₅ H ₁₁ Br)	<i>i</i> -C ₅ H ₁₁ SiCl ₃	23,8,16, 30
SiCl ₄ (330 g.)	4-BrC ₆ H ₄ MgBr (420 g. C ₆ H ₄ Br ₂)	4-BrC ₆ H ₄ SiCl ₃ (140 g.); (4-BrC ₆ H ₄) ₂ SiCl ₂ (60 g.)	32
SiCl ₄ (400 g.)	4-ClC ₆ H ₄ MgBr (382 g. C ₆ H ₄ BrCl)	4-ClC ₆ H ₄ SiCl ₃ (180 g.)	32
SiCl ₄ (150 g.)	C ₆ H ₅ MgBr (1 equiv.)	C ₆ H ₅ SiCl ₃ (83 g., crude)	30,33,34, 35,36
SiCl ₄ (170 g.)	C ₆ H ₅ MgBr (0.75 equiv.)	C ₆ H ₅ SiCl ₃ (ca. 100 g.)	37,38
SiCl ₄ (170 g.)	C ₆ H ₅ MgBr (2.25 equiv.)	C ₆ H ₅ SiCl ₃ (30 g.); (C ₆ H ₅) ₂ SiCl ₂ (110 g.); (C ₆ H ₅) ₃ SiCl (15 g.)	39,40
SiCl ₄ (8 g.)	C ₆ H ₅ MgBr (17 g.)	After hydrolysis: (C ₆ H ₅) ₂ Si(OH) ₂ (25-30%)	41
SiCl ₄ (1 mole)	C ₆ H ₅ MgBr (8 moles)	After hydrolysis: (C ₆ H ₅) ₃ SiOH	41
SiCl ₄ (10 g.)	C ₆ H ₅ MgBr (93 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₄ Si (48%)	42
SiCl ₄ (6 g.)	C ₆ H ₅ Br (30 g.) + Mg	(C ₆ H ₅) ₄ Si (8.8 g., 75%)	1
SiCl ₄ (35 g.)	(CH ₂) ₅ CHMgBr (2 equiv.)	(CH ₂) ₅ CHSiCl ₃ ; [(CH ₂) ₅ CH] ₂ SiCl ₂ ; conden'n products	49
SiCl ₄ (1.5 mole)	<i>n</i> -C ₆ H ₁₃ MgBr (1.5 mole)	<i>n</i> -C ₆ H ₁₃ SiCl ₃ (50%)	31,16,50
SiCl ₄	<i>n</i> -C ₆ H ₁₃ MgCl (93 g., ca. 2 equiv.)	(<i>n</i> -C ₆ H ₁₃) ₂ SiCl ₂ (38.5 g.)	16
SiCl ₄ (113.5 g.)	C ₆ H ₅ CH ₂ MgCl (84.2 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ SiCl ₃	23,3,16, 30,43
SiCl ₄	C ₆ H ₅ CH ₂ Cl + Mg	C ₆ H ₅ CH ₂ SiCl ₃ ; (C ₆ H ₅ CH ₂) ₂ SiCl ₂ ; (C ₆ H ₅ CH ₂) ₃ SiCl	15

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
SiCl₄ (cont.)			
SiCl ₄	C ₆ H ₅ CH ₂ MgCl (2.4 equiv.)	(C ₆ H ₅ CH ₂) ₂ SiCl ₂	44,45
SiCl ₄ (1 mole)	C ₆ H ₅ CH ₂ MgCl (3 moles)	After hydrolysis: (C ₆ H ₅ CH ₂) ₂ Si(OH) ₂ ("poor yield"); (C ₆ H ₅ CH ₂) ₃ SiOH	46
SiCl ₄ (1 mole)	C ₆ H ₅ CH ₂ MgCl (4 moles)	After hydrolysis: (C ₆ H ₅ CH ₂) ₃ SiOH ("good yield")	46
SiCl ₄ (12 g.)	C ₆ H ₅ CH ₂ MgCl (70.8 g. C ₇ H ₇ Cl)	(C ₆ H ₅ CH ₂) ₄ Si (45.1%)	42
SiCl ₄ (10 g.)	2-CH ₃ C ₆ H ₄ MgBr (55 g. C ₇ H ₇ Br)	Brown tar	1
SiCl ₄ (10 g.)	3-CH ₃ C ₆ H ₄ MgBr (55 g. C ₇ H ₇ Br)	(3-CH ₃ C ₆ H ₄) ₄ Si (1.8 g., 8%)	1
SiCl ₄ (10 g.)	4-CH ₃ C ₆ H ₄ MgBr (50 g. C ₇ H ₇ Br)	(4-CH ₃ C ₆ H ₄) ₄ Si (7 g., 30%)	1,47,48
SiCl ₄	<i>n</i> -C ₈ H ₁₇ MgBr	<i>n</i> -C ₈ H ₁₇ SiCl ₃	31
SiCl ₄ (113.5 g.)	1-C ₁₀ H ₇ MgBr (138 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ SiCl ₃	23,36
SiCl ₄ (113.4 g.)	1-C ₁₀ H ₇ MgBr (138 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ SiCl ₃ (53.2%)	16
SiCl ₄	<i>n</i> -C ₁₀ H ₂₁ MgBr	<i>n</i> -C ₁₀ H ₂₁ SiCl ₃ (54%)	31
SiCl ₄ (100 g.)	4-(C ₂ H ₅) ₃ SiC ₆ H ₄ MgBr (117 g. C ₁₂ H ₁₉ BrSi)	4-(C ₂ H ₅) ₃ SiC ₆ H ₄ SiCl ₃ (39 g., crude)	51
SiCl ₄ (140 parts)	<i>n</i> -C ₁₂ H ₂₅ MgCl (95 parts C ₁₂ H ₂₅ Cl)	<i>n</i> -C ₁₂ H ₂₅ SiCl ₃ (67%)	52
SiCl ₄	<i>n</i> -C ₁₂ H ₂₅ MgBr	<i>n</i> -C ₁₂ H ₂₅ SiCl ₃ (29%)	31
SiCl ₄	<i>n</i> -C ₁₄ H ₂₉ MgCl	<i>n</i> -C ₁₄ H ₂₉ SiCl ₃ (50%)	52
SiCl ₄	<i>n</i> -C ₁₄ H ₂₉ MgBr	<i>n</i> -C ₁₄ H ₂₉ SiCl ₃ (48%)	31
SiCl ₄	<i>n</i> -C ₁₈ H ₃₇ MgCl	<i>n</i> -C ₁₈ H ₃₇ SiCl ₃	52
SiBr₄			
SiBr ₄ (18 g.)	C ₆ H ₅ MgBr (45 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₄ Si (10 g., 60%)	1
Si₂Cl₆			
Si ₂ Cl ₆ (20 g.)	CH ₃ MgBr (11.2 g. Mg)	[(CH ₃) ₃ Si —] ₂ (0.9 g.)	30,59
Si ₂ Cl ₆ (20 g.)	C ₂ H ₅ MgBr (55 g. C ₂ H ₅ Br)	[(C ₂ H ₅) ₃ Si —] ₂ (9.0 g., 50%); (C ₂ H ₅) ₄ Si	1

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
Si₂Cl₆ (cont.)			
Si ₂ Cl ₆ (15 g.)	<i>n</i> -C ₃ H ₇ MgCl (50 g. C ₃ H ₇ Cl)	[(<i>n</i> -C ₃ H ₇) ₃ Si —] ₂ ("large yield"); (<i>n</i> -C ₃ H ₇) ₄ Si ("very little")	1
Si ₂ Cl ₆	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ SiCl ₂ and "other monosilane derivatives"	60
Si ₂ Cl ₆ (10 g.)	C ₆ H ₅ MgBr (55 g. C ₆ H ₅ Br)	[(C ₆ H ₅) ₃ Si —] ₂ (7 g., 40%); (C ₆ H ₅) ₄ Si (trace)	1
Si ₂ Cl ₆ (12 g.)	C ₆ H ₅ CH ₂ Cl (100 g.) + Mg (15 g.)	[(C ₆ H ₅ CH ₂) ₃ Si —] ₂	61
Si ₂ Cl ₆ (13 g.)	4-CH ₃ C ₆ H ₄ MgBr (70 g. C ₇ H ₇ Br)	[(4-CH ₃ C ₆ H ₄) ₃ Si —] ₂ (7 g., 35%)	1
Si₂Br₆			
Si ₂ Br ₆ (35 g.)	C ₆ H ₅ MgBr (85 g. C ₆ H ₅ Br)	[(C ₆ H ₅) ₃ Si —] ₂ (1 g.); (C ₆ H ₅) ₄ Si (15 g.)	1
Si₂Br₆O			
O(SiBr ₃) ₂ (25 g.)	C ₆ H ₅ MgBr (60 g. C ₆ H ₅ Br)	(C ₆ H ₅) ₃ SiOH	1
Si₂Cl₆O			
O(SiCl ₃) ₂ (1 mole)	CH ₃ MgCl (2.4 moles) + CH ₃ MgI (0.1 mole)	Si ₂ OCl ₄ (CH ₃) ₂ (0.56 mole, 56%)	62
O(SiCl ₃) ₂ (0.7 mole)	C ₂ H ₅ MgBr (0.875 mole)	Cl ₃ SiOSiCl ₂ C ₂ H ₅ (40%, crude; 24%, pure)	62
O(SiCl ₃) ₂ (1 mole)	C ₂ H ₅ MgBr (2.5 moles)	Si ₂ OCl ₄ (C ₂ H ₅) ₂ (87%, crude; 28%, pure)	62
O(SiCl ₃) ₂ (1 mole)	C ₂ H ₅ MgBr (3.75 moles)	Si ₂ OCl ₃ (C ₂ H ₅) ₃ (85%, crude; 29.5%, pure)	62
O(SiCl ₃) ₂ (1 mole)	C ₂ H ₅ MgBr (6.25 moles)	Si ₂ OCl ₂ (C ₂ H ₅) ₄ (78%, crude; 11%, pure); Si ₂ OCl(C ₂ H ₅) ₅ (12 g., crude)	62
O(SiCl ₃) ₂ (6 g.)	C ₆ H ₅ MgBr (30 g. C ₆ H ₅ Br)	O[Si(C ₆ H ₅) ₃] ₂ (45%); (C ₆ H ₅) ₃ SiOH	1
O(SiCl ₃) ₂ (1 mole)	C ₆ H ₅ MgBr (2.85 moles)	Si ₂ OCl ₄ (C ₆ H ₅) ₂ (0.175 mole, 17.5%)	62
Si₃Cl₈			
Si ₃ Cl ₈ (18 g.)	C ₆ H ₅ MgBr (80 g. C ₆ H ₅ Br)	[(C ₆ H ₅) ₃ Si —] ₂ ; (C ₆ H ₅) ₄ Si (2 g.)	1

TABLE XXII-I (Continued)

Si Comp'd	RMgX	Product(s)	Ref.
HSiCl₃			
HSiCl ₃	CH ₃ MgCl	HSiCl ₂ CH ₃	63
HSiCl ₃ (60 g.)	CH ₃ MgBr (175 g.)	HSi(CH ₃) ₃ ("poor yield")	65
HSiCl ₃ (0.86 mole)	CH ₃ MgBr (1.75 mole CH ₃ Br) + <i>n</i> -C ₃ H ₇ MgBr (0.86 mole C ₃ H ₇ Br)	HSi(CH ₃) ₂ <i>n</i> -C ₃ H ₇ (10 g., 12%)	66
HSiCl ₃ (0.1 mole)	C ₂ H ₅ MgCl (0.3 mole)	HSi(C ₂ H ₅) ₃ (10 ml.)	67
HSiCl ₃ (135.5 g.)	C ₂ H ₅ MgBr (1.25 mole)	HSiCl ₂ C ₂ H ₅ ; HSiCl(C ₂ H ₅) ₂ (19%)	63
HSiCl ₃ (3.0 moles)	C ₂ H ₅ MgBr (12.6 moles)	HSi(C ₂ H ₅) ₃ (70–78%)	68,43,66, 69,115
HSiCl ₃ (0.1 mole)	H ₂ C=CHCH ₂ MgBr (1 mole)	HSi(CH ₂ CH=CH ₂) ₃	67
HSiCl ₃ (0.65 mole)	<i>n</i> -C ₃ H ₇ MgBr (1.51 mole C ₃ H ₇ Br)	HSi(<i>n</i> -C ₃ H ₇) ₃ (45 g., 43%)	66
HSiCl ₃ (0.86 mole)	<i>n</i> -C ₃ H ₇ MgBr (0.86 mole C ₃ H ₇ Br) + CH ₃ MgBr (1.75 mole CH ₃ Br)	HSi(CH ₃) ₂ <i>n</i> -C ₃ H ₇ (10 g., 12%)	66
HSiCl ₃ (0.34 mole)	<i>i</i> -C ₃ H ₇ MgCl (1.5 mole)	After hydrolysis at –10 to –5° with dil. H ₂ SO ₄ : (<i>i</i> -C ₃ H ₇) ₂ SiHOH (?) (5.6 g., 11%); [(<i>i</i> -C ₃ H ₇) ₂ SiH] ₂ O (?) (15.8 g., 42%). After similar hydrolysis with dil. HCl, [(<i>i</i> -C ₃ H ₇) ₂ SiH] ₂ O (?) (67 g., 85%)	70
HSiCl ₃ (0.38 mole)	<i>n</i> -C ₄ H ₉ MgCl (0.35 mole)	<i>n</i> -C ₄ H ₉ SiHCl ₂ (4.0%)	115
HSiCl ₃ (0.20 mole)	<i>n</i> -C ₄ H ₉ MgCl (0.40 mole)	(<i>n</i> -C ₄ H ₉) ₂ SiHCl	115
HSiCl ₃ (0.10 mole)	<i>n</i> -C ₄ H ₉ MgCl (0.50 mole)	(<i>n</i> -C ₄ H ₉) ₃ SiH (5.0%)	115
HSiCl ₃ (0.30 mole)	<i>i</i> -C ₄ H ₉ MgCl (0.25 mole)	<i>i</i> -C ₄ H ₉ SiHCl ₂ (3.5%)	115
HSiCl ₃ (0.15 mole)	<i>i</i> -C ₄ H ₉ MgCl (0.30 mole)	(<i>i</i> -C ₄ H ₉) ₂ SiHCl (2.0%)	115
HSiCl ₃ (0.40 mole)	<i>i</i> -C ₅ H ₁₁ MgCl (0.35 mole)	<i>i</i> -C ₅ H ₁₁ SiHCl ₂	115
HSiCl ₃ (0.15 mole)	<i>i</i> -C ₅ H ₁₁ MgCl (0.30 mole)	(<i>i</i> -C ₅ H ₁₁) ₂ SiHCl (1.5%)	115
HSiCl ₃ (813 g.)	4-ClC ₆ H ₄ MgBr (1.97 mole)	HSiCl ₂ C ₆ H ₄ -4-Cl	72
HSiCl ₃ (6 moles)	C ₆ H ₅ MgCl (6 moles)	HSiCl ₂ C ₆ H ₅ (188 g.)	72
HSiCl ₃ (0.8 mole)	C ₆ H ₅ MgBr (0.37 mole C ₆ H ₅ Br)	HSiCl ₂ C ₆ H ₅ (26%, crude)	71
HSiCl ₃	C ₆ H ₅ MgBr	HSiCl ₂ C ₆ H ₅ ; HSiCl(C ₆ H ₅) ₂	63

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
HSiCl₃ (cont.)			
HSiCl ₃	C ₆ H ₅ MgBr	HSiCl(C ₆ H ₅) ₂	73
HSiCl ₃ (36.2 g.)	C ₆ H ₅ MgBr (185 g. C ₆ H ₅ Br)	HSi(C ₆ H ₅) ₃ (52 g., 73%)	74
HSiCl ₃ (0.20 mole)	(CH ₂) ₅ CHMgCl (0.80 mole)	[(CH ₂) ₅ CH] ₃ SiH (4.4%)	115
HSiCl ₃	C ₆ H ₅ CH ₂ MgCl (1 equiv.)	HSiCl ₂ CH ₂ C ₆ H ₅ ; HSiCl(CH ₂ C ₆ H ₅) ₂ ; HSi(CH ₂ C ₆ H ₅) ₃	67,63
HSiCl ₃	C ₆ H ₅ CH ₂ MgCl	HSiCl(CH ₂ C ₆ H ₅) ₂	73
HSiCl ₃ (0.3 mole)	C ₆ H ₅ CH ₂ MgCl (0.6 mole)	HSiCl(CH ₂ C ₆ H ₅) ₂ (26 ml.); HSi(CH ₂ C ₆ H ₅) ₃	67
HSiCl ₃ (0.1 mole)	C ₆ H ₅ CH ₂ MgCl (0.6 mole)	HSi(CH ₂ C ₆ H ₅) ₃ (67%)	67,115
HSiCl ₃ (0.50 mole)	C ₆ H ₅ CH ₂ MgCl (0.50 mole) + CH ₃ MgCl (0.50 mole)*	CH ₃ (C ₆ H ₅ CH ₂)SiHCl (2.4%)	115
HSiCl ₃ (0.80 mole)	C ₆ H ₅ CH ₂ MgCl (0.80 mole) + CH ₃ MgCl (1.60 mole)*	C ₆ H ₅ CH ₂ (CH ₃) ₂ SiH (16.5%)	115
HSiCl ₃ (0.45 mole)	C ₆ H ₅ CH ₂ MgCl (0.90 mole) + CH ₃ MgCl (0.50 mole)*	CH ₃ (C ₆ H ₅ CH ₂) ₂ SiH (22.1%)	115
HSiCl ₃ (1220 g.)	4-CH ₃ C ₆ H ₄ MgBr (144 g. Mg)	HSiCl ₂ C ₆ H ₄ -4-CH ₃ (219.7 g.)	72
HSiCl ₃ (478 g.)	4-CH ₃ C ₆ H ₄ MgBr (1450 g.)	HSiCl(C ₆ H ₄ -4-CH ₃) ₂ (41%)	73
HSiCl ₃ (1080 g.)	1-C ₁₀ H ₇ MgBr (2.36 moles)	HSiCl ₂ -1-C ₁₀ H ₇	72
CH₃SiCl₃			
CH ₃ SiCl ₃ (0.5 mole) + (CH ₃) ₂ SiCl ₂ (3.75 moles)	CH ₃ MgCl (500 ml., 4.1 M)	(CH ₃) ₃ SiCl (38.7 g., 0.35 mole); (CH ₃) ₂ SiCl ₂ (159.2 g., 1.23 mole); intermediate fraction (30.8 g.)	81
CH₄SiCl₂			
HSiCl ₂ CH ₃ (0.74 mole)	C ₂ H ₅ MgBr (1.56 mole C ₂ H ₅ Br)	HSi(C ₂ H ₅) ₂ CH ₃ (15 g., 20%)	66
HSiCl ₂ CH ₃ (0.39 mole)	<i>n</i> -C ₃ H ₇ MgBr (0.82 mole C ₃ H ₇ Br)	HSi(<i>n</i> -C ₃ H ₇) ₂ CH ₃ (25 g., 49%)	66
HSiCl ₂ CH ₃	C ₆ H ₅ MgBr	HSiCl(CH ₃)C ₆ H ₅	73

* The Grignard reagents were added successively to the ethereal halide in the order implied.

TABLE XXII-1 (Continued)

Si Comp'd	RMgX	Product(s)	Ref.
C₂H₄SiCl₄			
ClCH ₂ CH ₂ SiCl ₃ (0.5 mole)	CH ₃ MgBr (3 moles)	(CH ₃) ₄ Si (24 g., 55%); C ₂ H ₄ (equiv. 11.9 g. C ₂ H ₄ Br ₂)	75
ClCH ₂ CH ₂ SiCl ₃ (1.5 mole)	C ₂ H ₅ MgBr (7.6 moles)	(C ₂ H ₅) ₄ Si (0.75 mole, 50%); C ₂ H ₄ (equiv. 12.5 g. C ₂ H ₄ Br ₂)	75
CH ₃ CHClSiCl ₃ (1.0 mole)	CH ₃ MgBr (3.5 equiv.)	CH ₃ CHClSi(CH ₃) ₃ (72.3 g., 53%)	3
C₂H₅SiCl₃			
ClCH ₂ (CH ₃)SiCl ₂ + ClCH ₂ (CH ₃) ₂ SiCl	CH ₃ MgBr	ClCH ₂ Si(CH ₃) ₃	86
C ₂ H ₅ SiCl ₃ (53 g.)	CH ₃ MgBr (26 g. Mg)	C ₂ H ₅ Si(CH ₃) ₃ (14.5 g., crude; 8.3 g., pure)	8,31
C ₂ H ₅ SiCl ₃	CH ₃ MgI	C ₂ H ₅ Si(CH ₃) ₃	76
C ₂ H ₅ SiCl ₃ (55 g.)	<i>i</i> -C ₄ H ₉ MgBr (10 g. Mg)	C ₂ H ₅ (<i>i</i> -C ₄ H ₉)SiCl ₂ (13.2 g., crude)	8
C ₂ H ₅ SiCl ₃ (100 g.)	C ₆ H ₅ MgBr (1.1 equiv.)	C ₂ H ₅ SiCl ₃ (5-10 g.); C ₂ H ₅ (C ₆ H ₅)SiCl ₂ (40-50 g., crude)	13,30,70
C ₂ H ₅ SiCl ₃	C ₆ H ₅ CH ₂ MgCl (1 equiv.)	C ₂ H ₅ (C ₆ H ₅ CH ₂)SiCl ₂ (60-80%)*	77,78
C ₂ H ₅ SiCl ₃	C ₆ H ₅ CH ₂ Cl (1 equiv.) + Mg (1 equiv.)	C ₂ H ₅ (C ₆ H ₅ CH ₂)SiCl ₂ (60-70%)†	79
C ₂ H ₅ SiCl ₃ (150 g.)	C ₆ H ₅ CH ₂ Cl (2 equiv.) + Mg (1 equiv.)	C ₂ H ₅ (C ₆ H ₅ CH ₂) ₂ SiCl (40-50%)‡	80
C₂H₆SiCl₂			
(CH ₃) ₂ SiCl ₂ (3.75 moles) + CH ₃ SiCl ₃ (0.5 mole)	CH ₃ MgCl (500 ml., 4.1 M)	(CH ₃) ₃ SiCl (38.7 g., 0.35 mole); (CH ₃) ₂ SiCl ₂ (159.2 g., 1.23 mole); intermediate fraction (30.8 g.)	81
(CH ₃) ₂ SiCl ₂ (24 moles)	C ₂ H ₅ MgBr (18.35 moles C ₂ H ₅ Br)	C ₂ H ₅ (CH ₃) ₂ SiCl (8.33 moles); C ₂ H ₅ (CH ₃) ₂ SiBr (1.506 mole); (CH ₃) ₂ (C ₂ H ₅) ₂ Si (0.723 mole)§	71

* Dropwise addition of Grignard solution to cooled, stirred Et₂O-halide solution; twelve to twenty-four hours at room temperature.

† Gradual addition of benzyl chloride to cooled, stirred suspension of magnesium in Et₂O-halide solution.

‡ Slow (two and one-half hours) dropwise addition of benzyl chloride to cooled, stirred suspension of magnesium in Et₂O-halide solution; three to four hours reflux.

§ Accidental loss of some material during course of reaction.

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₂H₆SiCl₂ (cont.)			
(CH ₃) ₂ SiCl ₂ (0.39 mole)	(CH ₃) ₃ SiCH ₂ MgCl (0.8 mole chloride)	(CH ₃) ₂ Si[CH ₂ Si(CH ₃) ₃] ₂ (0.25 mole, 65%)	82
(CH ₃) ₂ SiCl ₂ (5.5 moles)	(CH ₃) ₃ SiOSi(CH ₃) ₂ CH ₂ MgCl (5 moles chloride)	After hydrolysis and hydrofluorination: H ₂ C[Si(CH ₃) ₂ F] ₂ (532 g., 63%)	83
(CH ₃) ₂ SiCl ₂ (1.2 mole)	(CH ₃) ₃ SiOSi(CH ₃) ₂ CH ₂ MgCl (2.5 moles chloride)	After hydrolysis: (CH ₃) ₃ SiOSi(CH ₃) ₂ CH ₂ Si(CH ₃) ₃ (7%); H ₂ C[(CH ₃) ₂ SiOSi(CH ₃) ₃] ₂ (22%); [(CH ₃) ₃ SiOSi(CH ₃) ₂ CH ₂] ₂ Si(CH ₃) ₂ (10%). Residue, after hydrofluorination, yielded H ₂ C[Si(CH ₃) ₂ F] ₂ (48%)	83
HSiCl ₂ C ₂ H ₅	C ₂ H ₅ MgCl (excess)	HSi(C ₂ H ₅) ₃ (50-55%)	84
HSiCl ₂ C ₂ H ₅	C ₆ H ₅ MgBr	HSiCl(C ₂ H ₅)C ₆ H ₅	73
HSiCl ₂ C ₂ H ₅	C ₆ H ₅ CH ₂ MgCl	HSiCl(C ₂ H ₅)CH ₂ C ₆ H ₅	73
C₂H₆SiO			
[(CH ₃) ₂ SiO] _x (66 g., 0.89 equiv.)	CH ₃ Mgl (0.92 mole)	(CH ₃) ₃ SiOH (3.3 g.)	88
C₃H₅SiCl₃			
H ₂ C=CHCH ₂ SiCl ₃	CH ₃ MgBr	CH ₃ (H ₂ C=CHCH ₂)SiCl ₂	89
C₃H₇SiCl₃			
<i>n</i> -C ₃ H ₇ SiCl ₃ (50 g.)	CH ₃ MgBr (22.6 g. Mg)	<i>n</i> -C ₃ H ₇ (CH ₃) ₃ Si (25.5 g., crude; 13.5 g., pure)	8,31
<i>n</i> -C ₃ H ₇ SiCl ₃ (56 g.)	C ₂ H ₅ MgBr (9.2 g. Mg)	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)SiCl ₂ (ca. 26 g., crude)	8
<i>n</i> -C ₃ H ₇ SiCl ₃ (18 g.)	C ₂ H ₅ MgBr (12.5 g. Mg)	<i>n</i> -C ₃ H ₇ (C ₂ H ₅) ₃ Si (4.5 g.)	30,76
<i>n</i> -C ₃ H ₇ SiCl ₃	C ₂ H ₅ MgBr	<i>n</i> -C ₃ H ₇ (C ₂ H ₅) ₃ Si (71%)	31
CH ₃ (ClCH ₂) ₂ SiCl	CH ₃ MgBr (sl. excess)	(ClCH ₂) ₂ (CH ₃) ₂ Si (63%)	90
Cl ₂ CH(CH ₃) ₂ SiCl	CH ₃ MgBr (sl. excess)	Cl ₂ CH(CH ₃) ₃ Si (70%)	90

TABLE XXII-I (Continued)

Si Comp'd	RMgX	Product(s)	Ref.
C₃H₈SiCl₂			
HSiCl ₂ - <i>i</i> -C ₃ H ₇	4-ClC ₆ H ₄ MgBr	HSiCl(<i>i</i> -C ₃ H ₇)C ₆ H ₄ -4-Cl	73
ClCH ₂ (CH ₃) ₂ SiCl	CH ₃ MgBr	ClCH ₂ (CH ₃) ₃ Si (90%)	85,86
ClCH ₂ (CH ₃) ₂ SiCl	CH ₃ MgBr	ClCH ₂ (CH ₃) ₃ Si	86
+ ClCH(CH ₃)SiCl ₂			
ClCH ₂ (CH ₃) ₂ SiCl	(CH ₃) ₃ SiCH ₂ MgCl	ClCH ₂ (CH ₃) ₂ SiCH ₂ Si(CH ₃) ₃ (32%)	82
ClCH ₂ (CH ₃) ₂ SiCl	C ₆ H ₅ MgBr	ClCH ₂ (CH ₃) ₂ SiC ₆ H ₅ (72%)	110
C₃H₉SiCl			
(CH ₃) ₃ SiCl (0.5 mole)	C ₂ H ₅ MgBr (0.5 mole)	After hydrolysis: C ₂ H ₅ (CH ₃) ₃ Si (0.18 mole);	91
+ (C ₂ H ₅) ₃ SiCl (0.5 mole)		(C ₂ H ₅) ₄ Si (0.095 mole, crude);	
		(CH ₃) ₃ SiOSi(C ₂ H ₅) ₃ (0.091 mole);	
		[(C ₂ H ₅) ₃ Si] ₂ O (0.101 mole)	
(CH ₃) ₃ SiCl (5 moles)	H ₂ C=CHCH ₂ MgBr (5.8 equiv.)	H ₂ C=CHCH ₂ (CH ₃) ₃ Si (51%)	95
(CH ₃) ₃ SiCl (0.5 mole)	<i>n</i> -C ₃ H ₇ MgBr (0.5 mole)	After hydrolysis: <i>n</i> -C ₃ H ₇ (CH ₃) ₃ Si (0.287	91
+ (C ₂ H ₅) ₃ SiCl (0.5 mole)		mole); [(C ₂ H ₅) ₃ Si] ₂ O (0.13 mole);	
		(CH ₃) ₃ SiOSi(C ₂ H ₅) ₃ (0.045 mole)	
(CH ₃) ₃ SiCl (0.5 mole)	(CH ₃) ₃ SiCH ₂ MgCl (0.5 mole C ₃ H ₁₁ ClSi)	[(CH ₃) ₃ Si] ₂ CH ₂ (0.31 mole, 63%)	82,87
(CH ₃) ₃ SiCl (81 g.)	4-BrC ₆ H ₄ MgBr (177 g. C ₆ H ₄ Br ₂)	4-BrC ₆ H ₄ (CH ₃) ₃ Si (90.5 g., 53%)	92
(CH ₃) ₃ SiCl (220 g.)	4-ClC ₆ H ₄ MgBr (382 g. C ₆ H ₄ BrCl)	4-ClC ₆ H ₄ (CH ₃) ₃ Si (305 g., 83%)	92
(CH ₃) ₃ SiCl (100 g.)	(CH ₃) ₃ SiOSi(CH ₃) ₂ CH ₂ MgCl (200 g. C ₅ H ₁₇ ClOSi ₂)	(CH ₃) ₃ SiOSi(CH ₃) ₂ CH ₂ Si(CH ₃) ₃ (150 ml.)	93,94
(CH ₃) ₃ SiCl	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ (CH ₃) ₃ Si (74%)	96
(CH ₃) ₃ SiCl	<i>n</i> -C ₇ H ₁₅ MgBr	<i>n</i> -C ₇ H ₁₅ (CH ₃) ₃ Si (46%)	31
(CH ₃) ₃ SiCl (0.37 mole)	<i>n</i> -C ₁₂ H ₂₅ MgBr (0.6 mole)	<i>n</i> -C ₁₂ H ₂₅ (CH ₃) ₃ Si (56%)	31
C₄H₉SiCl₃			
<i>n</i> -C ₄ H ₉ SiCl ₃ (30 g.)	CH ₃ MgBr (12.4 g. Mg)	<i>n</i> -C ₄ H ₉ (CH ₃) ₃ Si (11.4 g.)	8,31

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₄H₉SiCl₃ (cont.)			
<i>n</i> -C ₄ H ₉ SiCl ₃ (25.5 g.)	C ₂ H ₅ MgBr (14 g. Mg)	<i>n</i> -C ₄ H ₉ (C ₂ H ₅) ₃ Si (6.4 g.)	30
<i>i</i> -C ₄ H ₉ SiCl ₃ (50 g.)	C ₂ H ₅ MgBr (7.8 g. Mg)	C ₂ H ₅ (<i>i</i> -C ₄ H ₉)SiCl ₂ (16 g., crude)	8
<i>i</i> -C ₄ H ₉ SiCl ₃ (29 g.)	C ₂ H ₅ MgBr (17 g. Mg)	<i>i</i> -C ₄ H ₉ (C ₂ H ₅) ₃ Si (6.2 g.)	30,76
<i>t</i> -C ₄ H ₉ SiCl ₃ (0.1 mole)	CH ₃ MgBr (0.5 mole)	<i>t</i> -C ₄ H ₉ (CH ₃) ₃ Si (61%)	97,98
C₄H₁₀SiCl₂			
(C ₂ H ₅) ₂ SiCl ₂ (24.5 g.)	CH ₃ MgI (9.8 g. Mg)	(CH ₃) ₂ (C ₂ H ₅) ₂ Si (<i>ca.</i> 6 g.)	8
(C ₂ H ₅) ₂ SiCl ₂ (10 g.)	H ₂ C=CHCH ₂ MgBr (37 g. C ₃ H ₅ Br)	(C ₂ H ₅) ₂ (H ₂ C=CHCH ₂) ₂ Si (55-60%)	99
(C ₂ H ₅) ₂ SiCl ₂ (11 g.)	H ₂ C(CH ₂ CH ₂ MgBr) ₂ (24 g. C ₅ H ₁₀ Br ₂)	(CH ₂) ₅ Si(C ₂ H ₅) ₂ (<i>ca.</i> 2 g.)	29
C₅H₁₀SiCl₂			
(CH ₂) ₅ SiCl ₂ (23.2 g.)	CH ₃ MgBr (8.3 g. Mg)	(CH ₂) ₅ Si(CH ₃) ₂	29
C₅H₁₁SiCl₃			
<i>i</i> -C ₅ H ₁₁ SiCl ₃ (30 g.)	CH ₃ MgBr (11.5 g. Mg)	<i>i</i> -C ₅ H ₁₁ (CH ₃) ₃ Si (19 g., crude)	8,31
<i>i</i> -C ₅ H ₁₁ SiCl ₃ (37.5 g.)	C ₂ H ₅ MgBr (20 g. Mg)	<i>i</i> -C ₅ H ₁₁ (C ₂ H ₅) ₃ Si (12.5 g.)	30,76
C₅H₁₂SiCl₂			
C ₂ H ₅ (<i>n</i> -C ₃ H ₇)SiCl ₂ (21.3 g.)	CH ₃ MgBr (7.2 g. Mg)	C ₂ H ₅ (<i>i</i> -C ₃ H ₇)(CH ₃) ₂ Si (13.3 g., crude)	8
C₆H₄SiCl₃Br			
4-BrC ₆ H ₄ SiCl ₃ (40 g.)	C ₂ H ₅ MgBr (70 g. C ₂ H ₅ Br)	4-BrC ₆ H ₄ (C ₂ H ₅) ₃ Si (34 g., 91%)	32,51
C₆H₄SiCl₄			
4-ClC ₆ H ₄ SiCl ₃	C ₂ H ₅ MgBr	4-ClC ₆ H ₄ (C ₂ H ₅) ₃ Si (88%)	32
C₆H₅SiCl₃			
C ₆ H ₅ SiCl ₃ (67 g.)	CH ₃ MgBr (26 g. Mg)	C ₆ H ₅ (CH ₃) ₃ Si (37.5 g.)	30,76

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₅SiCl₃ (cont.)			
C ₆ H ₅ SiCl ₃ (30 g.)	C ₂ H ₅ MgBr (14.5 g. Mg)	C ₆ H ₅ (C ₂ H ₅) ₃ Si (17.5 g.)	30,33,43
C ₆ H ₅ SiCl ₃ (220 g.)	4-BrC ₆ H ₄ MgBr (265 g. C ₆ H ₄ Br ₂)	4-BrC ₆ H ₄ (C ₆ H ₅)SiCl ₂	51
C ₆ H ₅ SiCl ₃ (211 g.)	(CH ₂) ₅ CHMgBr (480 g. C ₆ H ₁₁ Br)	C ₆ H ₅ [(CH ₂) ₅ CH] ₂ SiCl (5-20 g.); (CH ₂) ₅ CH(C ₆ H ₅)SiCl ₂ (15-20 g., crude)	100
C ₆ H ₅ SiCl ₃ (10 g.)	(CH ₂) ₅ CHMgBr (100 g. C ₆ H ₁₁ Br)	C ₆ H ₅ [(CH ₂) ₅ CH] ₂ SiOCH(CH ₂) ₅ (15 g., crude)	101
C ₆ H ₅ SiCl ₃ * (50 g.)	(CH ₂) ₅ CHMgBr (large excess)	HSi[CH(CH ₂) ₅] ₂ C ₆ H ₅ (40 g.); C ₆ H ₅ [(CH ₂) ₅ CH] ₂ SiOCH(CH ₂) ₅ (20 g.); C ₆ H ₅ [(CH ₂) ₅ CH] ₂ SiOH and conden'n products of C ₆ H ₅ [(CH ₂) ₅ CH]Si(OH) ₂ (10 g.)	101
C ₆ H ₅ SiCl ₃	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ (C ₆ H ₅ CH ₂)SiCl ₂	102
C₆H₈SiO₃			
C ₆ H ₅ Si(OH) ₃ (10 g.)	C ₆ H ₅ MgBr (large excess)	(C ₆ H ₅) ₃ SiOH (5 g.)	103
C₆H₁₃SiCl₃			
<i>n</i> -C ₆ H ₁₃ SiCl ₃ (0.5 mole)	CH ₃ MgBr (1.7 mole)	<i>n</i> -C ₆ H ₁₃ (CH ₃) ₃ Si (79%)	31
C₆H₁₄SiFCl			
ClCH ₂ CH ₂ (C ₂ H ₅) ₂ SiF (0.27 mole)	CH ₃ MgBr (0.64 equiv.)	(CH ₃) ₂ (C ₂ H ₅) ₂ Si (0.16 mole, 59%); C ₂ H ₄ (36%)	105
C₆H₁₄SiCl₂			
(<i>n</i> -C ₃ H ₇) ₂ SiCl ₂ (crude)	CH ₃ MgBr	(CH ₃) ₂ (<i>n</i> -C ₃ H ₇) ₂ Si (impure)	8
C ₂ H ₅ (<i>i</i> -C ₄ H ₉)SiCl ₂ (23 g.)	CH ₃ MgBr (6.9 g. Mg)	C ₂ H ₅ (<i>i</i> -C ₄ H ₉)(CH ₃) ₂ Si (6 g.)	8

* This reaction was conducted under an atmosphere of nitrogen.

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₄SiCl₂ (cont.)			
ClCH ₂ CH ₂ (C ₂ H ₅) ₂ SiCl (0.33 mole)	CH ₃ MgBr (0.93 equiv.)	(CH ₃) ₂ (C ₂ H ₅) ₂ Si (0.19 mole, 57.5%); C ₂ H ₄ (25%)	105
CH ₃ CHCl(C ₂ H ₅) ₂ SiCl (0.33 mole)	CH ₃ MgBr (0.5 mole)	CH ₃ (CH ₃ CHCl)(C ₂ H ₅) ₂ Si (0.29 mole, 87%)	104
CH ₃ CHCl(C ₂ H ₅) ₂ SiCl (0.38 mole)	C ₆ H ₅ MgBr (0.67 mole)	CH ₃ CHCl(C ₆ H ₅)(C ₂ H ₅) ₂ Si (0.20 mole, 57%)	104
C₆H₁₅SiBr			
(C ₂ H ₅) ₃ SiBr	C ₆ H ₅ MgBr	"Unsuccessful"	43
(C ₂ H ₅) ₃ SiBr (10 g.)	C ₆ H ₅ CH ₂ MgCl (12.6 g. C ₇ H ₇ Cl)	C ₆ H ₅ CH ₂ (C ₂ H ₅) ₃ Si (5.5 g., 50%)	43
C₆H₁₅SiCl			
(C ₂ H ₅) ₃ SiCl	CH ₃ MgBr	CH ₃ (C ₂ H ₅) ₃ Si (60%)	31
(C ₂ H ₅) ₃ SiCl (0.42 mole)	CH ₃ MgBr (0.42 mole) + C ₂ H ₅ MgBr (0.42 mole)	CH ₃ (C ₂ H ₅) ₃ Si (0.28 mole); <i>no</i> (C ₂ H ₅) ₄ Si	91
(C ₂ H ₅) ₃ SiCl (0.5 mole) + (CH ₃) ₃ SiCl (0.5 mole)	C ₂ H ₅ MgBr (0.5 mole)	After hydrolysis: C ₂ H ₅ (CH ₃) ₃ Si (0.18 mole); (C ₂ H ₅) ₄ Si (0.095 mole, crude; (CH ₃) ₃ SiOSi(C ₂ H ₅) ₃ (0.091 mole); [(C ₂ H ₅) ₃ Si] ₂ O (0.101 mole)	91
(C ₂ H ₅) ₃ SiCl (0.5 mole) + (CH ₃) ₃ SiCl (0.5 mole)	<i>n</i> -C ₃ H ₇ MgBr (0.5 mole)	After hydrolysis: <i>n</i> -C ₃ H ₇ (CH ₃) ₃ Si (0.287 mole); [(C ₂ H ₅) ₃ Si] ₂ O (0.13 mole); (CH ₃) ₃ SiOSi(C ₂ H ₅) ₃ (0.045 mole)	91
(C ₂ H ₅) ₃ SiCl	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ (C ₂ H ₅) ₃ Si (50%)	31
(C ₂ H ₅) ₃ SiCl	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₅ H ₁₁ (C ₂ H ₅) ₃ Si (75%)	31
(C ₂ H ₅) ₃ SiCl	CH ₃ CH=C(CH ₃)C≡CMgX	CH ₃ CH=C(CH ₃)C≡C(C ₂ H ₅) ₃ Si	106
(C ₂ H ₅) ₃ SiCl	<i>n</i> -C ₆ H ₁₃ MgBr	<i>n</i> -C ₆ H ₁₃ (C ₂ H ₅) ₃ Si (60%)	31
(C ₂ H ₅) ₃ SiCl	<i>n</i> -C ₇ H ₁₅ MgBr	<i>n</i> -C ₇ H ₁₅ (C ₂ H ₅) ₃ Si (68%)	31
C₆H₁₅SiClO₃			
(C ₂ H ₅ O) ₃ SiCl	C ₂ H ₅ MgBr	C ₂ H ₅ (C ₂ H ₅ O) ₃ Si	107

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₆H₁₅SiClO₃ (<i>cont.</i>)			
(C ₂ H ₅ O) ₃ SiCl	C ₆ H ₅ MgBr	C ₆ H ₅ (C ₂ H ₅ O) ₃ Si	107
C₆H₁₅Si₂Cl₃O			
Si ₂ OCl ₃ (C ₂ H ₅) ₃ (293 g., crude)	C ₂ H ₅ MgBr (<i>ca.</i> 2.5 equiv.)	Si ₂ OCl(C ₂ H ₅) ₅ (12.5%, pure)	62
C₆H₁₆SiO₂			
(CH ₃) ₂ Si(OC ₂ H ₅) ₂	CH ₃ Cl + Mg	(CH ₃) ₃ SiOC ₂ H ₅ (73%)	108
C₆H₁₇Si₂Cl			
(CH ₃) ₃ SiCH ₂ Si(CH ₃) ₂ Cl	CH ₃ MgBr	[(CH ₃) ₃ Si] ₂ CH ₂	111
C₆H₁₈Si₂O₄S			
[(CH ₃) ₃ Si] ₂ SO ₄ (0.33 mole)	C ₂ H ₅ MgBr (0.9 mole)	C ₂ H ₅ (CH ₃) ₃ Si (0.55 mole, 83.5%)	109
[(CH ₃) ₃ Si] ₂ SO ₄ (0.3 mole)	<i>n</i> -C ₃ H ₇ MgBr (0.8 mole)	<i>n</i> -C ₃ H ₇ (CH ₃) ₃ Si (55%); (CH ₃) ₃ SiBr	109
[(CH ₃) ₃ Si] ₂ SO ₄ * (0.3 mole)	<i>i</i> -C ₃ H ₇ MgBr (0.7 mole)	(CH ₃) ₃ SiBr (0.31 mole, 51.5%)	109
[(CH ₃) ₃ Si] ₂ SO ₄ † (0.3 mole)	<i>i</i> -C ₃ H ₇ MgBr (0.7 mole)	<i>i</i> -C ₃ H ₇ (CH ₃) ₃ Si (0.155 mole, 34%)	109
C₇H₇SiCl₃			
C ₆ H ₅ CH ₂ SiCl ₃ (41 g.)	CH ₃ MgBr (14 g. Mg)	C ₆ H ₅ CH ₂ (CH ₃) ₃ Si (20 g., crude; 11.5 g., pure)	8
C ₆ H ₅ CH ₂ SiCl ₃	C ₂ H ₅ MgBr	C ₆ H ₅ CH ₂ (C ₂ H ₅) ₃ Si (40%)	43

* Addition of Et₂O-sulfate solution to Grignard solution; one hour stirring at room temperature; distillation of volatile material on steam-bath (six hours).

† Addition of Et₂O-sulfate solution to Grignard solution; eight days reflux with stirring; distillation of volatile material on steam-bath (six hours).

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₇H₁₀SiO₃			
C ₆ H ₅ CH ₂ Si(OH) ₃ *	C ₆ H ₅ CH ₂ MgCl (large excess)	(C ₆ H ₅ CH ₂) ₃ SiOH	103
C₈H₁₀SiCl₂			
C ₂ H ₅ (C ₆ H ₅)SiCl ₂ (10.5 g.)	CH ₃ MgBr (6 g. Mg)	C ₂ H ₅ (C ₆ H ₅)(CH ₃) ₂ Si (7.4 g.)	8
C ₂ H ₅ (C ₆ H ₅)SiCl ₂	CH ₃ MgI	CH ₃ (C ₂ H ₅)(C ₆ H ₅)SiCl	77
C ₂ H ₅ (C ₆ H ₅)SiCl ₂	<i>n</i> -C ₃ H ₇ MgBr (1 equiv.)	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅)SiCl; C ₂ H ₅ (C ₆ H ₅)(<i>n</i> -C ₃ H ₇) ₂ Si	13a,77,78
C₈H₁₀SiO			
[C ₂ H ₅ (C ₆ H ₅)SiO] _x	CH ₃ MgI	CH ₃ (C ₂ H ₅)(C ₆ H ₅)SiOH	103
[C ₂ H ₅ (C ₆ H ₅)SiO] _x	C ₂ H ₅ MgBr	C ₆ H ₅ (C ₂ H ₅) ₂ SiOH	103
C₈H₁₇SiCl₃			
<i>n</i> -C ₈ H ₁₇ SiCl ₃	CH ₃ MgBr	<i>n</i> -C ₈ H ₁₇ (CH ₃) ₃ Si (89%)	31
<i>n</i> -C ₈ H ₁₇ SiCl	C ₂ H ₅ MgBr	<i>n</i> -C ₈ H ₁₇ (C ₂ H ₅) ₃ Si (77%)	31
C₈H₂₀SiO₄			
Si(OC ₂ H ₅) ₄	CH ₃ Cl + Mg	(CH ₃) ₂ Si(OC ₂ H ₅) ₂ ; CH ₃ Si(OC ₂ H ₅) ₃	118,112
Si(OC ₂ H ₅) ₄ (1.5 mole)	CH ₃ MgI (2.5 moles CH ₃ I)	CH ₃ Si(OC ₂ H ₅) ₃ ; (CH ₃) ₂ Si(OC ₂ H ₅) ₂ ; CH ₃ SiO ₂ C ₂ H ₅ (?)	113
Si(OC ₂ H ₅) ₄	C ₂ H ₅ Cl + Mg	Products not separable by fractional distillation	118
Si(OC ₂ H ₅) ₄ (7 moles)	C ₂ H ₅ MgBr (22 moles)	(C ₂ H ₅) ₃ SiOC ₂ H ₅ , yielding, upon hydrolysis, [(C ₂ H ₅) ₃ Si] ₂ O (2.3 moles, 66%)	114
Si(OC ₂ H ₅) ₄ (104 g.)	C ₂ H ₅ MgBr (1 equiv.) + Mg (12 g.)	C ₂ H ₅ Si(OC ₂ H ₅) ₃ (61%)	50,35

* It is now generally agreed that triplicate silicanetriols are not isolable; if they exist at all they immediately undergo dehydration-condensation to form "polymers".

TABLE XXII-I (Continued)

Si Comp'd	RMgX	Product(s)	Ref.
C₈H₂₀SiO₄ (cont.)			
Si(OC ₂ H ₅) ₄ (220 ml.)	C ₂ H ₅ MgBr (170 ml.) + Mg (55 g.)	After hydrolysis: "resinous diethyl silicanol"	116
Si(OC ₂ H ₅) ₄	H ₂ C=CHCH ₂ Cl + Mg	H ₂ C=CHCH ₂ Si(OC ₂ H ₅) ₃ (50%)	117
Si(OC ₂ H ₅) ₄	H ₂ C=CHCH ₂ Br + Mg	H ₂ C=CHCH ₂ Si(OC ₂ H ₅) ₃ (55.1%)	117
Si(OC ₂ H ₅) ₄	<i>n</i> -C ₃ H ₇ MgBr + Mg	<i>n</i> -C ₃ H ₇ Si(OC ₂ H ₅) ₃	35
Si(OC ₂ H ₅) ₄	<i>i</i> -C ₃ H ₇ MgBr + Mg	<i>i</i> -C ₃ H ₇ Si(OC ₂ H ₅) ₃ (20.2%)	50
Si(OC ₂ H ₅) ₄ (2080 g.)	<i>n</i> -C ₄ H ₉ MgCl (360 g. Mg)	<i>n</i> -C ₄ H ₉ Si(OC ₂ H ₅) ₃ (215 g.); (<i>n</i> -C ₄ H ₉) ₂ Si(OC ₂ H ₅) ₂ (595 g.)	118
Si(OC ₂ H ₅) ₄ (1 mole)	<i>n</i> -C ₄ H ₉ MgBr (1 mole)	<i>n</i> -C ₄ H ₉ Si(OC ₂ H ₅) ₃ (27%)	113
Si(OC ₂ H ₅) ₄ (0.825 mole)	<i>n</i> -C ₄ H ₉ MgBr (4 moles)	(<i>n</i> -C ₄ H ₉) ₄ Si (56%)	113
Si(OC ₂ H ₅) ₄	RCI + Mg (R = <i>n</i> -C ₄ H ₉ , <i>n</i> -C ₅ H ₁₁)	RSi(OC ₂ H ₅) ₃ ; R ₂ Si(OC ₂ H ₅) ₂ ; R ₃ SiOC ₂ H ₅	119
Si(OC ₂ H ₅) ₄	<i>i</i> -C ₄ H ₉ X + Mg	<i>i</i> -C ₄ H ₉ Si(OC ₂ H ₅) ₃ (71%)	50
Si(OC ₂ H ₅) ₄	<i>i</i> -C ₅ H ₁₁ X + Mg	<i>i</i> -C ₅ H ₁₁ Si(OC ₂ H ₅) ₃ (48%)	50
Si(OC ₂ H ₅) ₄ (10 g.)	C ₆ H ₅ MgBr (7.6 g. C ₆ H ₅ Br)	C ₆ H ₅ Si(OC ₂ H ₅) ₃	120
Si(OC ₂ H ₅) ₄	C ₆ H ₅ Br + Mg	C ₆ H ₅ Si(OC ₂ H ₅) ₃	35
Si(OC ₂ H ₅) ₄	<i>n</i> -C ₆ H ₁₃ X + Mg	<i>n</i> -C ₆ H ₁₃ Si(OC ₂ H ₅) ₃ (50.3%)	50
Si(OC ₂ H ₅) ₄ (220 ml.)	4-CH ₃ C ₆ H ₄ MgBr (275 ml.) + Mg (55 g.)	(4-CH ₃ C ₆ H ₄) ₂ Si(OC ₂ H ₅) ₂	116
Si(OC ₂ H ₅) ₄ (330 g.)	C ₆ H ₅ C≡CMgBr (152 g. C ₆ H ₅ C≡CH)	C ₆ H ₅ C≡CSi(OC ₂ H ₅) ₃ (75%)	12
Si(OC ₂ H ₅) ₄	2,4-(CH ₃) ₂ C ₆ H ₃ MgI	2,4-(CH ₃) ₂ C ₆ H ₃ Si(OC ₂ H ₅) ₃	120
Si(OC ₂ H ₅) ₄ (10 g.)	1-C ₁₀ H ₇ MgBr (10 g. C ₁₀ H ₇ Br)	1-C ₁₀ H ₇ Si(OC ₂ H ₅) ₃	120
Si(OC ₂ H ₅) ₄ (10 g.)	2-C ₁₀ H ₇ MgI (12 g. C ₁₀ H ₇ I)	2-C ₁₀ H ₇ Si(OC ₂ H ₅) ₃	120
C₈H₂₂Si₂O			
(CH ₃) ₃ SiCH ₂ Si(CH ₃) ₂ OC ₂ H ₅	CH ₃ MgBr	[(CH ₃) ₂ Si] ₂ CH ₂	111
C₉H₁₂SiCl₂			
C ₂ H ₅ (C ₆ H ₅ CH ₂)SiCl ₂	<i>n</i> -C ₃ H ₇ MgBr (1 equiv.)	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)C ₆ H ₅ CH ₂ SiCl (50-60%); C ₂ H ₅ (C ₆ H ₅ CH ₂)(<i>n</i> -C ₃ H ₇) ₂ Si	77,78

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₉H₁₂SiCl₂ (cont.)			
C ₂ H ₅ (C ₆ H ₅ CH ₂)SiCl ₂	<i>n</i> -C ₃ H ₇ MgBr (excess)	C ₂ H ₅ (C ₆ H ₅ CH ₂)(<i>n</i> -C ₃ H ₇) ₂ Si	121
C ₂ H ₅ (C ₆ H ₅ CH ₂)SiCl ₂	<i>i</i> -C ₄ H ₉ MgBr (1 equiv.)	C ₂ H ₅ (<i>i</i> -C ₄ H ₉)(C ₆ H ₅ CH ₂)SiCl (ca. 40%)	79
C₉H₁₂SiO			
[C ₂ H ₅ (C ₆ H ₅ CH ₂)SiO] _x	C ₂ H ₅ MgBr (1.5 equiv.)	C ₆ H ₅ CH ₂ (C ₂ H ₅) ₂ SiOH	103
[C ₂ H ₅ (C ₆ H ₅ CH ₂)SiO] _x	<i>n</i> -C ₃ H ₇ MgBr (1.5 equiv.)	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅ CH ₂)SiOH	103
C₉H₂₅Si₃Cl			
(CH ₃) ₃ Si[CH ₂ Si(CH ₃) ₂] ₂ Cl	CH ₃ MgBr	(CH ₃) ₂ Si[CH ₂ Si(CH ₃) ₃] ₂	111
C₁₀H₂₁SiCl₃			
<i>n</i> -C ₁₀ H ₂₁ SiCl ₃	CH ₃ MgBr	<i>n</i> -C ₁₀ H ₂₁ (CH ₃) ₃ Si (80%)	31
<i>n</i> -C ₁₀ H ₂₁ SiCl ₃	C ₂ H ₅ MgBr	<i>n</i> -C ₁₀ H ₂₁ (C ₂ H ₅) ₃ Si (78%)	31
C₁₁H₁₇SiCl			
C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅)SiCl	CH ₃ MgI (excess)	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₃ H ₇)(C ₆ H ₅)Si	13b
C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅)SiCl	C ₆ H ₅ CH ₂ MgCl	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅)(C ₆ H ₅ CH ₂)Si (50-60%)	121
C₁₁H₃₀Si₃O			
(CH ₃) ₃ Si[CH ₂ Si(CH ₃) ₂] ₂ OC ₂ H ₅	CH ₃ MgBr	(CH ₃) ₂ Si[CH ₂ Si(CH ₃) ₃] ₂	111
C₁₂H₉SiCl₂Br			
4-BrC ₆ H ₄ (C ₆ H ₅)SiCl ₂ (82 g.)	C ₂ H ₅ MgBr (5 equiv.)	4-BrC ₆ H ₄ (C ₆ H ₅)(C ₂ H ₅) ₂ Si; 4-C ₂ H ₅ C ₆ H ₄ (C ₆ H ₅)(C ₂ H ₅) ₂ Si	51
C₁₂H₁₀SiCl₂			
(C ₆ H ₅) ₂ SiCl ₂	CH ₃ MgI (excess)	(CH ₃) ₂ (C ₆ H ₅) ₂ Si	122

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₂H₁₀SiCl₂O₂			
(C ₆ H ₅ O) ₂ SiCl ₂	C ₂ H ₅ MgBr	(C ₂ H ₅) ₂ Si(OC ₂ H ₅) ₂	45
(C ₆ H ₅ O) ₂ SiCl ₂	C ₆ H ₅ MgBr (2 equiv.)	After hydrolysis: (C ₆ H ₅) ₂ Si(OH) ₂	123
C₁₂H₁₉SiCl			
C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅ CH ₂)SiCl	CH ₃ MgI	CH ₃ (C ₂ H ₅)(<i>n</i> -C ₃ H ₇)(C ₆ H ₅ CH ₂)Si (<i>ca.</i> 60%)	77,78
C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(C ₆ H ₅ CH ₂)SiCl	<i>i</i> -C ₃ H ₇ MgBr	C ₂ H ₅ (<i>n</i> -C ₃ H ₇)(<i>i</i> -C ₃ H ₇)(C ₆ H ₅ CH ₂)Si (60%)	125
C₁₂H₁₉Si₂Cl₃			
4-[(C ₂ H ₅) ₃ Si]C ₆ H ₄ SiCl ₃ (40 g.)	C ₂ H ₅ MgBr (97 g. C ₂ H ₅ Br)	1,4-[(C ₂ H ₅) ₃ Si] ₂ C ₆ H ₄ (<i>ca.</i> 15.5 g.)	51
C₁₂H₂₇SiClO₃			
(<i>i</i> -C ₄ H ₉ O) ₃ SiCl	C ₂ H ₅ MgBr	C ₂ H ₅ Si(O- <i>i</i> -C ₄ H ₉) ₃	107
(<i>i</i> -C ₄ H ₉ O) ₃ SiCl	C ₆ H ₅ MgBr	C ₆ H ₅ Si(O- <i>i</i> -C ₄ H ₉) ₃	107
C₁₄H₁₄SiO			
[(C ₆ H ₅ CH ₂) ₂ SiO] ₃	CH ₃ MgI	CH ₃ (C ₆ H ₅ CH ₂) ₂ SiOH	103
C₁₄H₁₆SiO₂			
(C ₆ H ₅ CH ₂) ₂ Si(OH) ₂	CH ₃ MgI (large excess)	CH ₃ (C ₆ H ₅ CH ₂) ₂ SiOH	103
C₁₄H₂₉SiCl₃			
<i>n</i> -C ₁₄ H ₂₉ SiCl ₃	CH ₃ MgBr	<i>n</i> -C ₁₄ H ₂₉ (CH ₃) ₃ Si (50%)	31
C₁₄H₃₈SiO₄			
(CH ₃) ₃ Si[CH ₂ Si(CH ₃) ₂] ₃ OC ₂ H ₅	CH ₃ MgBr	[(CH ₃) ₃ SiCH ₂ Si(CH ₃) ₂] ₂ CH ₂	111
C₁₅H₃₃SiClO₃			
(<i>i</i> -C ₅ H ₁₁ O) ₃ SiCl	C ₂ H ₅ MgBr	C ₂ H ₅ Si(O- <i>i</i> -C ₅ H ₁₁) ₃	107

TABLE XXII-I (Continued)

<u>Si Comp'd</u>	<u>RMgX</u>	<u>Product(s)</u>	<u>Ref.</u>
C₁₅H₃₃SiClO₃ (<i>cont.</i>)			
(<i>i</i> -C ₅ H ₁₁ O) ₃ SiCl	C ₆ H ₅ MgBr	C ₆ H ₅ Si(O- <i>i</i> -C ₅ H ₁₁) ₃	107
C₁₈H₁₅SiCl			
(C ₆ H ₅) ₃ SiCl	CH ₃ MgI (<i>excess</i>)	CH ₃ (C ₆ H ₅) ₃ Si	121
(C ₆ H ₅) ₃ SiCl	C ₂ H ₅ MgBr (<i>excess</i>)	C ₂ H ₅ (C ₆ H ₅) ₃ Si	121,76
C₁₈H₁₅SiClO₃			
(C ₆ H ₅ O) ₃ SiCl	C ₆ H ₅ MgBr	C ₆ H ₅ Si(OC ₆ H ₅) ₃	123
C₁₈H₂₇SiBr			
C ₆ H ₅ [(CH ₂) ₅ CH] ₂ SiBr	C ₂ H ₅ MgBr	C ₂ H ₅ (C ₆ H ₅)[(CH ₂) ₅ CH] ₂ Si	101
C₄₈H₄₀Si₄I₂			
[(C ₆ H ₅) ₂ Si] ₄ I ₂	C ₂ H ₅ MgBr (<i>large excess</i>)	[(C ₆ H ₅) ₂ Si] ₄ (C ₂ H ₅) ₂	124
[(C ₆ H ₅) ₂ Si] ₄ I ₂	C ₆ H ₅ MgBr (<i>large excess</i>)	No reaction	124

REFERENCES FOR TABLE XXII-I

- (1) Schumb and Saffer, *J. Am. Chem. Soc.*, 61, 363-6 (1939).
- (2) Gilliam, Liebhafsky, and Winslow, *J. Am. Chem. Soc.*, 63, 801-3 (1941).
- (3) Sommer and Whitmore, *J. Am. Chem. Soc.*, 68, 485-7 (1946).
- (4) Booth and Martin, *J. Am. Chem. Soc.*, 68, 2655-7 (1946).
- (5) Hyde, U. S. Patent 2,413,049, Dec. 24, 1946; *Chem. Abstr.*, 41, P2069 (1947).
- (6) Booth and Suttle, *J. Am. Chem. Soc.*, 68, 2658-60 (1946).
- (7) Pearlson, Brice, and Simons, *J. Am. Chem. Soc.*, 67, 1769-70 (1945).
- (8) Bygdén, *Ber.*, 44, 2640-52 (1911).
- (9) Whitmore and Sommer, *J. Am. Chem. Soc.*, 68, 481-4 (1946).
- (10) Helm and Mack, *J. Am. Chem. Soc.*, 59, 60-2 (1937).
- (10.1) Dennis and Hance, *J. Phys. Chem.*, 30, 1055-9 (1926).
- (11) Aston, Kennedy, and Messerly, *J. Am. Chem. Soc.*, 63, 2343-8 (1941).
- (12) Vol'nov and Reutt, *J. Gen. Chem. (U.S.S.R.)*, 10, 1600-4 (1940); *Chem. Abstr.*, 35, 2853 (1941).
- (13) Kipping, (a) *Proc. Chem. Soc.*, 20, 15-6 (1904); (b) *J. Chem. Soc.*, 91, 209-40 (1907).
- (14) Booth and Cornell, *J. Am. Chem. Soc.*, 68, 2650-2 (1946).
- (15) Martin and Kipping, *J. Chem. Soc.*, 95, 302-14 (1909).
- (16) Andrianov, *J. Gen. Chem. (U.S.S.R.)*, 41, 487-92 (1946); *Chem. Abstr.*, 41, 701 (1947).
- (17) Larsson, *Trans. Chalmers Univ. Technol., Gothenberg, Swed.*, No. 79, 3-6 (1948); *Chem. Abstr.*, 43, 2928 (1949).
- (18) Alfrey, Honn, and Mark, *J. Polymer Sci.*, 1, 102-20 (1946); *Chem. Abstr.*, 40, 3396 (1946).
- (19) Sugden and Wilkins, *J. Chem. Soc.*, 1931, 126-8.
- (20) Tseng and Chao, *Science Repts. Natl. Univ. Peking*, 1, No. 4, 21-37 (1936); *Chem. Abstr.*, 31, 655 (1937).
- (21) Kropa, U. S. Patent 2,388,161, Oct. 30, 1945; *Chem. Abstr.*, 40, P592 (1946).
- (22) Meads and Kipping, *J. Chem. Soc.*, 107, 459-68 (1915).
- (23) Melzer, *Ber.*, 41, 3390-5 (1908).
- (24) Sommer, Dorfman, Goldberg, and Whitmore, *J. Am. Chem. Soc.*, 68, 488-9 (1946).
- (25) Booth and Halbedel, *J. Am. Chem. Soc.*, 68, 2652-4 (1946).
- (26) Booth and Spessard, *J. Am. Chem. Soc.*, 68, 2660-2 (1946).
- (27) Krause and Renwanz, *Ber.*, 62B, 1710-6 (1929).
- (28) Booth and Schwarz, *J. Am. Chem. Soc.*, 68, 2662-5 (1946).
- (29) Bygdén, *Ber.*, 48, 1236-42 (1915).
- (30) Bygdén, *Ber.*, 45, 707-13 (1912).
- (31) Whitmore, Sommer, Di Giorgio, Van Strien, Bailey, Hall, Pietrusza, and Kerr, *J. Am. Chem. Soc.*, 68, 475-81 (1946).
- (32) Grüttner and Krause, *Ber.*, 50, 1559-68 (1917).
- (33) Ipatiew and Dolgow, *Ber.*, 62B, 1220-6 (1929).
- (34) Kipping, *J. Chem. Soc.*, 105, 679-90 (1914).
- (35) Post and Hofrichter, *J. Org. Chem.*, 4, 363-4 (1938).
- (36) Koton, *J. Applied Chem. (U.S.S.R.)*, 12, 1435-9 (1939); *Chem. Abstr.*, 34, 6242 (1940).
- (37) Kipping, Murray, and Maltby, *J. Chem. Soc.*, 1929, 1180-91.
- (38) Meads and Kipping, *J. Chem. Soc.*, 105, 679-90 (1914).
- (39) Kipping, *J. Chem. Soc.*, 101, 2108-25 (1912).
- (40) Kipping and Murray, *J. Chem. Soc.*, 1927, 2734-7.
- (41) Dilthey and Eduardoff, *Ber.*, 37, 1139-42 (1904).

- (42) Manulkin and Yakubova, *J. Gen. Chem. (U.S.S.R.)*, 10, 1300-2 (1940); *Chem. Abstr.*, 35, 3240 (1941).
- (43) Kraus and Nelson, *J. Am. Chem. Soc.*, 56, 195-202 (1934).
- (44) Robison and Kipping, *J. Chem. Soc.*, 93, 439-56 (1908).
- (45) Hanford, U. S. Patent 2,386,793, Oct. 16, 1945; *Chem. Abstr.*, 40, P604 (1946).
- (46) Dilthey, *Ber.*, 38, 4132-6 (1905).
- (47) Pink and Kipping, *J. Chem. Soc.*, 123, 2830-7 (1923).
- (48) Steele and Kipping, *J. Chem. Soc.*, 1929, 2545-50.
- (49) Palmer and Kipping, *J. Chem. Soc.*, 1930, 1020-8.
- (50) Andrianov and Gribanova, *J. Gen. Chem. (U.S.S.R.)*, 8, 552-6 (1938); *Chem. Abstr.*, 32, 7892 (1938).
- (51) Grüttner and Cauer, *Ber.*, 51, 1283-92 (1918).
- (52) Hyde, U. S. Patent 2,413,050, Dec. 24, 1946; *Chem. Abstr.*, 41, P2069 (1947).
- (53) Gierut, Sowa, and Nieuwland, *J. Am. Chem. Soc.*, 58, 897-8 (1936).
- (54) Jaeger and Dijkstra, *Z. anorg. Chem.*, 143, 233-58 (1935).
- (55) Medoks and Kotelkov, *J. Gen. Chem. (U.S.S.R.)*, 7, 2007-8 (1937); *Chem. Abstr.*, 32, 531 (1938).
- (56) Medoks, *J. Gen. Chem. (U.S.S.R.)*, 8, 291-3 (1938); *Chem. Abstr.*, 32, 5392 (1938).
- (57) Manulkin, *J. Gen. Chem. (U.S.S.R.)*, 16, 235-42 (1946); *Chem. Abstr.*, 41, 90 (1947).
- (58) Soshestvenskaya, *J. Gen. Chem. (U.S.S.R.)*, 8, 294-6 (1938); *Chem. Abstr.*, 32, 5392 (1938).
- (59) Martin, *Ber.*, 46, 2442-7 (1913).
- (60) Schwarz and Sexauer, *Ber.*, 59B, 333-7 (1926).
- (61) Schumb and Saffer, *J. Am. Chem. Soc.*, 63, 93-5 (1941).
- (62) Emeléus and Payne, *J. Chem. Soc.*, 1947, 1590-2.
- (63) Emeléus and Robinson, *J. Chem. Soc.*, 1947, 1592-4.
- (64) de Man, van Steenis, and Waterman, *Rec. trav. chim.*, 67, 864-8 (1948).
- (65) Taylor and Walden, *J. Am. Chem. Soc.*, 66, 842-3 (1944).
- (66) Price, *J. Am. Chem. Soc.*, 69, 2600-4 (1947).
- (67) Jenkins, Lavery, Guenther, and Post, *J. Org. Chem.*, 13, 862-6 (1948).
- (68) Whitmore, Pietrusza, and Sommer, *J. Am. Chem. Soc.*, 69, 2108-10 (1947).
- (69) Meals, *J. Am. Chem. Soc.*, 68, 1880-1 (1946).
- (70) Gilman and Clark, *J. Am. Chem. Soc.*, 69, 1499-500 (1947).
- (71) Lewis, *J. Am. Chem. Soc.*, 69, 717 (1947).
- (72) Barry, British Patent 618,403, Feb. 21, 1949; *Chem. Abstr.*, 43, P5801 (1949).
- (73) Barry, British Patent 622,970, May 10, 1949; *Chem. Abstr.*, 44, P658 (1950).
- (74) Reynolds, Bigelow, and Kraus, *J. Am. Chem. Soc.*, 51, 3067-72 (1929).
- (75) Sommer, Goldberg, Dorfman, and Whitmore, *J. Am. Chem. Soc.*, 68, 1083-5 (1946).
- (76) Dolgov and Volnov, *Zhur. Obsheĩ Khim.*, Khim. Ser., I, 91-104 (1931); *Chem. Abstr.*, 25, 4535 (1931).
- (77) Kipping, *Proc. Chem. Soc.*, 21, 65-6 (1905).
- (78) Kipping, *J. Chem. Soc.*, 91, 717-47 (1907).
- (79) Luff and Kipping, *J. Chem. Soc.*, 93, 2004-16 (1908).
- (80) Challenger and Kipping, *J. Chem. Soc.*, 97, 142-54 (1910).
- (81) Gilliam and Sauer, *J. Am. Chem. Soc.*, 66, 1793 (1944).
- (82) Sommer, Goldberg, Gold, and Whitmore, *J. Am. Chem. Soc.*, 69, 980 (1947).
- (83) Bluestein, *J. Am. Chem. Soc.*, 70, 3068-71 (1948).
- (84) Meals, *J. Am. Chem. Soc.*, 68, 1880-1 (1946).
- (85) Whitmore, Sommer, and Gold, *J. Am. Chem. Soc.*, 69, 1976-7 (1947).

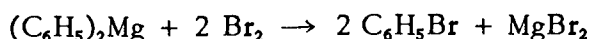
- (86) Roedel, *J. Am. Chem. Soc.*, 71, 269-72 (1949).
(87) Sommer, Mitch, and Goldberg, *J. Am. Chem. Soc.*, 71, 2746-50 (1949).
(88) Sauer, *J. Am. Chem. Soc.*, 66, 1707-10 (1944).
(89) Hurd, U. S. Patent 2,420,912, May 20, 1947; *Chem. Abstr.*, 41, P5145 (1947).
(90) Speier and Daubert, *J. Am. Chem. Soc.*, 70, 1400-1 (1948).
(91) Sommer, Kerr, and Whitmore, *J. Am. Chem. Soc.*, 70, 434-5 (1948).
(92) Burkhard, *J. Am. Chem. Soc.*, 68, 2103 (1946).
(93) Speier, U. S. Patent 2,444,858, July 6, 1948; *Chem. Abstr.*, 42, P7317 (1948).
(94) Corning Glass Works, British Patent 621,009, Apr. 1, 1949; *Chem. Abstr.*, 43, P7500 (1949).
(95) Sommer, Tyler, and Whitmore, *J. Am. Chem. Soc.*, 70, 2872-4 (1948).
(96) Gilman and Marshall, *J. Am. Chem. Soc.*, 71, 2066-9 (1949).
(97) Tyler, Sommer, and Whitmore, *J. Am. Chem. Soc.*, 69, 981 (1947).
(98) Tyler, Sommer, and Whitmore, *J. Am. Chem. Soc.*, 70, 2876-8 (1948).
(99) Yakovlev, *J. Gen. Chem. (U.S.S.R.)*, 19, 1969-70 (1949); *Chem. Abstr.*, 44, 1016 (1950).
(100) Cusa and Kipping, *J. Chem. Soc.*, 1932, 2205-9.
(101) Cusa and Kipping, *J. Chem. Soc.*, 1933, 1040-3.
(102) Robison and Kipping, *J. Chem. Soc.*, 101, 2156-66 (1912).
(103) Kipping and Hackford, *J. Chem. soc.*, 99, 138-45 (1911).
(104) Sommer, Bailey, Strong, and Whitmore, *J. Am. Chem. Soc.*, 68, 1881-3 (1946).
(105) Gold, Sommer, and Whitmore, *J. Am. Chem. Soc.*, 70, 2874-6 (1948).
(106) Bowden, Braude, and Jones, *J. Chem. Soc.*, 1946, 948-52.
(107) Kalinin, *Compt. rend. acad. Sci. U.R.S.S.*, 26, 365-9 (1940); *Chem. Abstr.*, 35, 2470 (1941).
(108) Daudt, U. S. Patent 2,390,518, Dec. 11, 1945; *Chem. Abstr.*, 40, P1866 (1946).
(109) Sommer, Kerr, and Whitmore, *J. Am. Chem. Soc.*, 70, 445-7 (1948).
(110) Sommer, Gold, Goldberg, and Marans, *J. Am. Chem. Soc.*, 71, 1509 (1949).
(111) Goodwin, British Patent 631,619, Nov. 7, 1949; *Chem. Abstr.*, 44, 4491 (1950).
(112) McGregor and Warrick, U. S. Patent 2,384,384, Sept. 4, 1945; *Chem. Abstr.*, 40, P730 (1946).
(113) Post and Hofrichter, *J. Org. Chem.*, 5, 572-8 (1940).
(114) Di Giorgio, Strong, Sommer, and Whitmore, *J. Am. Chem. Soc.*, 68, 1380 (1946).
(115) Jenkins and Post, *J. Org. Chem.*, 15, 552-5 (1950).
(116) Hackford, Shaw, and Smith, British Patent 591,149, Aug. 8, 1947; *Chem. Abstr.*, 42, P586 (1948).
(117) Andrianov and Kamenskaya, *J. Gen. Chem. (U.S.S.R.)*, 8, 969-71 (1938); *Chem. Abstr.*, 33, 1266 (1939).
(118) McGregor and Warrick, U. S. Patent 2,442,053, May 25, 1948; *Chem. Abstr.*, 42, P7786 (1948).
(119) McGregor and Warrick, U. S. Patent 2,380,057, July 10, 1945; *Chem. Abstr.*, 40, P88 (1946).
(120) Khotinsky and Seregenkoff, *Ber.*, 41, 2946-53 (1908).
(121) Marsden and Kipping, *Proc. Chem. Soc.*, 24, 12 (1908); *J. Chem. Soc.*, 93, 198-210 (1908).
(122) Kipping, *J. Chem. Soc.*, 1927, 104-7.
(123) Jörg and Stetter, *J. prakt. Chem.*, [2], 117, 305-10 (1927).
(124) Kipping, *J. Chem. Soc.*, 123, 2598-603 (1923).
(125) Davies and Kipping, *J. Chem. Soc.*, 95, 69-80 (1909).
(126) Kohlschütter, Scheele, and Jaekel, Unpublished work, as cited by: Kohlschütter, *Fortschritte chem. Forschung*, 1, 1-60 (1949).

CHAPTER XXIII

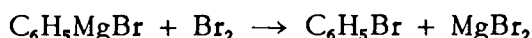
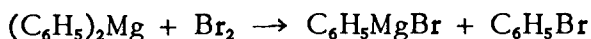
Reactions of Grignard Reagents with Miscellaneous Non-metallic Substances

HALOGENS

It is probable that the first halogenation of a Grignard reagent was unwittingly effected by Fleck.¹ In one of several attempts to prepare the then unknown organomagnesium halides, he treated diphenylmagnesium with bromine. Unfortunately, he used an excess of bromine and arrived at the conclusions that the reaction takes the course



and that no stable intermediate of the formula $\text{C}_6\text{H}_5\text{MgBr}$ is formed. Gilman and Brown² have since shown that in all probability the reaction occurs stepwise:



The iodination of Grignard reagents and attempts by Jolibois,³ Leroide,⁴ and Job and Reich⁵ to use iodine titration as a method for quantitative estimation of organomagnesium compounds, as well as a critique of the method by Gilman *et al.*⁶ are discussed in Chapter III on Estimation and Detection of Grignard Reagents (*q.v.*).

More recently, calorimetric measurements of the reactions of methylmagnesium iodide with iodine have been used by Mackle and Ubbelohde⁷ as a basis for the estimation of the heats of dissociation: $D_{(\text{CH}_3-\text{I})}$ and $D_{(\text{CH}_3-\text{Mg})}$.

Published data on other halogenations of Grignard reagents are summarized in Table XXIII-I.

In general it would appear that the better yields of halides (RX') might be expected when the Grignard reagent (RMgX) solution is added to an excess of a cold halogen (X'_2) solution.⁸ When "coupling" is possible

¹ Fleck, *Ann.*, 276, 129-47 (1893).

² Gilman and Brown, *J. Am. Chem. Soc.*, 52, 1181-5 (1930).

³ Jolibois, *Compt. rend.*, 155, 213-5 (1912); *Chem. Abstr.*, 6, 2740 (1912).

⁴ Leroide, *Ann. chim.*, [9], 16, 354-410 (1921).

⁵ Job and Reich, *Bull. soc. chim.*, [4], 33, 1414-33 (1923).

⁶ Gilman, Wilkinson, Fishel, and Meyers, *J. Am. Chem. Soc.*, 45, 150-8 (1923).

⁷ Mackle and Ubbelohde, *J. Chem. Soc.*, 1948, 1161-70

⁸ *Cf.*, e.g., Gilman and Vernon, *J. Am. Chem. Soc.*, 48, 1063-6 (1926).

TABLE XXIII-I

REACTIONS OF GRIGNARD REAGENTS WITH HALOGENS

<u>RMgX</u>	<u>X'</u> ₂	<u>RX'</u>	<u>2 R*</u>	<u>Ref.</u>
(\equiv CMgBr) ₂	Br ₂	(\equiv CBr ₂) ₂ ; (\equiv CBr) ₂ (?)	...	2
(\equiv CMgBr) ₂	I ₂	(\equiv CI) ₂	...	2, c/. 19
C ₂ H ₅ MgBr	I ₂	C ₂ H ₅ I (<20%)	...	6
C ₂ H ₅ MgI	Br ₂	C ₂ H ₅ Br	...	6
<i>n</i> -C ₃ H ₇ MgBr	I ₂	<i>n</i> -C ₃ H ₇ I (80%)	...	1a
<i>i</i> -C ₃ H ₇ MgI	Br ₂	<i>i</i> -C ₃ H ₇ Br (30-40%)	...	6
<i>n</i> -C ₃ H ₇ C \equiv CMgBr	I ₂	<i>n</i> -C ₃ H ₇ C \equiv CI (69-76%) [†]	...	7
<i>n</i> -C ₃ H ₇ C \equiv CMgBr	I ₂	<i>n</i> -C ₃ H ₇ C \equiv CI (77%)	...	10
<i>n</i> -C ₃ H ₇ C \equiv CMgX (2 equiv.)	I ₂	...	(<i>n</i> -C ₃ H ₇ C \equiv C—) ₂	19
<i>i</i> -C ₃ H ₇ C \equiv CMgBr	I ₂	<i>i</i> -C ₃ H ₇ C \equiv CI (33%)	...	3
<i>i</i> -C ₅ H ₁₁ MgCl	I ₂	<i>i</i> -C ₅ H ₁₁ I (80%)	...	1a
<i>t</i> -C ₄ H ₉ CH ₂ MgCl	Br ₂	<i>t</i> -C ₄ H ₉ CH ₂ Br (82%)	...	15
<i>t</i> -C ₄ H ₉ CH ₂ MgCl	I ₂	<i>t</i> -C ₄ H ₉ CH ₂ I (88%, crude)	...	15
4-BrC ₆ H ₄ MgBr	I ₂	4-BrC ₆ H ₄ I	...	1b
C ₆ H ₅ MgBr	Cl ₂	? [†]	...	6
C ₆ H ₅ MgBr	Br ₂	C ₆ H ₅ Br (30-40%)	(C ₆ H ₅ —) ₂	6
C ₆ H ₅ MgBr [§]	I ₂	C ₆ H ₅ I (25-30%)	(C ₆ H ₅ —) ₂	6, 1a
C ₆ H ₅ MgBr [¶]	I ₂	C ₆ H ₅ I (90%)	...	6
C ₆ H ₅ MgI	Cl ₂	C ₆ H ₅ Cl (20-25%)	...	6
C ₆ H ₅ MgI	Br ₂	C ₆ H ₅ Br (30-40%)	(C ₆ H ₅ —) ₂	6
C ₆ H ₅ MgI	I ₂	C ₆ H ₅ I	(C ₆ H ₅ —) ₂ (chief product)	6
2-CH ₃ C ₆ H ₄ MgBr [¶]	I ₂	2-CH ₃ C ₆ H ₄ I (80%)	...	6
3-CH ₃ C ₆ H ₄ MgBr [¶]	I ₂	3-CH ₃ C ₆ H ₄ I (76%)	...	6
4-CH ₃ C ₆ H ₄ MgBr	Cl ₂	4-CH ₃ C ₆ H ₄ Cl (18-20%)	...	6
4-CH ₃ C ₆ H ₄ MgBr	I ₂	4-CH ₃ C ₆ H ₄ I	...	1a
4-CH ₃ C ₆ H ₄ MgBr [¶]	I ₂	4-CH ₃ C ₆ H ₄ I (74%)	...	6
<i>n</i> -C ₅ H ₁₁ C \equiv CMgBr	I ₂	<i>n</i> -C ₅ H ₁₁ C \equiv CI (69-76%) [†]	...	7
<i>n</i> -C ₅ H ₁₁ C \equiv CMgX (2 equiv.)	I ₂	...	(<i>n</i> -C ₅ H ₁₁ C \equiv C—) ₂	19
(C ₂ H ₅ O) ₂ CHC \equiv CMgBr	I ₂	(C ₂ H ₅ O) ₂ CHC \equiv CI	...	8, 18
C ₆ H ₅ C \equiv CMgBr	Br ₂	C ₆ H ₅ C \equiv CBr	...	2
C ₆ H ₅ C \equiv CMgBr	I ₂	(?), m.p. 99-100°	...	2
C ₆ H ₅ C \equiv CMgX	I ₂	...	(C ₆ H ₅ C \equiv C—) ₂	19
C ₆ H ₅ OC \equiv CMgBr	I ₂	C ₆ H ₅ OCI=Cl ₂ (60%)	...	16
[C ₆ H ₅ CH(CO ₂ Na)] ⁻ MgX ⁺	Br ₂	C ₆ H ₅ CHBrCO ₂ H	...	12
(CH ₂) ₅ CHC \equiv CMgBr	I ₂	(CH ₂) ₅ CHC \equiv CI (69-76%) [†]	...	7

* The symbol 2 R is intended to include both coupling products (R₂) and disproportionation products [R_(+H) + R_(-H)].

[†] This is the range of yields reported for RC \equiv CI when R is aliphatic.

[‡] Reaction explosive.

[§] Normal order of addition (I₂ to C₆H₅MgBr).

[¶] Reversed order of addition (RMgX solution to I₂ solution).

TABLE XXIII-I (Continued)

<u>RMgX</u>	<u>X'₂</u>	<u>RX'</u>	<u>2 R*</u>	<u>Ref.</u>
$n\text{-C}_6\text{H}_{13}\text{C}\equiv\text{CMgBr}$	I_2	$n\text{-C}_6\text{H}_{13}\text{C}\equiv\text{Cl}$ (88%)	...	11
$\text{C}_6\text{H}_5\text{CH}_2\text{C}\equiv\text{CMgBr}$ (1 equiv.)	I_2	$\text{C}_6\text{H}_5\text{CH}_2\text{C}\equiv\text{Cl}$	...	7
$\text{C}_6\text{H}_5\text{CH}_2\text{C}\equiv\text{CMgX}$ (2 equiv.)	I_2	...	$(\text{C}_6\text{H}_5\text{CH}_2\text{C}\equiv\text{C}-)_2$	19
1-Indenyl-MgBr	Br_2	1,2,3-Tribromoindane + 1-bromoindene (?)	...	4
1-Indenyl-MgBr	I_2	...	1,1'-Biindenyl (82%)	4
2-HO-5- $\text{CH}_3\text{C}_6\text{H}_3\text{C}\equiv\text{CMgBr}$	I_2	2-HO-5- $\text{CH}_3\text{C}_6\text{H}_4\text{C}\equiv\text{Cl}$ (66-68%) [†]	...	7
$\text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{C}\equiv\text{CMgBr}$ (1 equiv.)	I_2	$\text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{C}\equiv\text{Cl}$	...	7
$\text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{C}\equiv\text{CMgBr}$ (2 equiv.)	I_2	...	$(\text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{C}\equiv\text{C}-)_2$	19
2,4-(CH_3) ₂ $\text{C}_6\text{H}_3\text{C}\equiv\text{CMgBr}$ (1 equiv.)	I_2	2,4-(CH_3) ₂ $\text{C}_6\text{H}_3\text{C}\equiv\text{Cl}$ (66-68%) [†]	...	7
2,4-(CH_3) ₂ $\text{C}_6\text{H}_3\text{C}\equiv\text{CMgBr}$ (2 equiv.)	I_2	...	$[2,4-(\text{CH}_3)_2\text{C}_6\text{H}_3\text{C}\equiv\text{C}-]_2$ (80%)	7,19
$n\text{-C}_8\text{H}_{17}\text{C}\equiv\text{CMgBr}$	I_2	$n\text{-C}_8\text{H}_{17}\text{C}\equiv\text{Cl}$ (70%)	...	11
$n\text{-C}_9\text{H}_{19}\text{C}\equiv\text{CMgBr}$	I_2	$n\text{-C}_9\text{H}_{19}\text{C}\equiv\text{Cl}$ (69-76%) [†]	...	7
1- $\text{C}_{10}\text{H}_7\text{C}\equiv\text{CMgBr}$ (1 equiv.)	I_2	$n\text{-C}_{10}\text{H}_7\text{C}\equiv\text{Cl}$	...	7
1- $\text{C}_{10}\text{H}_7\text{C}\equiv\text{CMgBr}$ (2 equiv.)	I_2	...	$(1\text{-C}_{10}\text{H}_7\text{C}\equiv\text{C}-)_2$ (82%)	7
4-(C_2H_5) ₃ $\text{SiC}_6\text{H}_4\text{MgBr}$	I_2	4-(C_2H_5) ₃ $\text{SiC}_6\text{H}_4\text{I}$ (82%)	...	5
$n\text{-C}_{10}\text{H}_{21}\text{C}\equiv\text{CMgBr}$	I_2	$n\text{-C}_{10}\text{H}_{21}\text{C}\equiv\text{Cl}$ (95%)	...	11
$n\text{-C}_{12}\text{H}_{25}\text{MgCl}$	I_2	$n\text{-C}_{12}\text{H}_{25}\text{I}$ (71.0%) + $n\text{-C}_{12}\text{H}_{25}\text{Cl}$ (16.4%)	$n\text{-C}_{24}\text{H}_{50}$ (5.1%) + $\text{C}_{12}\text{H}_{26}$ + $\text{C}_{12}\text{H}_{24}$ (4.3%)	14
9-Anthryl-MgBr	I_2	9-Iodoanthracene (53%)	...	17
10-Phenyl-9-anthryl-MgBr	I_2	9-Iodo-10-phenyl-anthracene (50-55%)	...	13
$(\text{C}_6\text{H}_5)_2\text{C}=\text{C}(\text{C}_6\text{H}_5)\text{MgBr}$	I_2	$(\text{C}_6\text{H}_5)_2\text{C}=\text{C}(\text{C}_6\text{H}_5)\text{I}$ (52%)	...	9

* The symbol 2 R is intended to include both coupling products (R_2) and disproportionation products [$\text{R}_{(+\text{H})} + \text{R}_{(-\text{H})}$].

[†] This is the range of yields reported for $\text{RC}\equiv\text{Cl}$ when R is aliphatic.

[‡] This is the range of yields reported for $\text{RC}\equiv\text{Cl}$ when R is aromatic.

REFERENCES FOR TABLE XXIII-I

- (1) Bodroux, (a) *Compt. rend.*, 135, 1350-1 (1902); *J. Chem. Soc.*, 84,1, 221 (1903); (b) *Compt. rend.*, 136, 1138-9 (1903); *J. Chem. Soc.*, 84,1, 592 (1903).
- (2) Iotsitch, *J. Russ. Phys.-Chem. Soc.*, 35, 1269-75 (1903); *Bull. soc. chim.*, [3], 181 (1905).
- (3) Kalinine, *J. Russ. Phys.-Chem. Soc.*, 38, 1042-6 (1907); *Chem. Abstr.*, 1, 1271 (1907).
- (4) Grignard and Courtot, *Compt. rend.*, 154, 361-4 (1912); *Chem. Abstr.*, 6, 1132 (1912).

- (5) Grüttner and Krause, *Ber.*, 50, 1559-68 (1917).
- (6) Datta and Mitter, *J. Am. Chem. Soc.*, 41, 287-92 (1919).
- (7) Grignard and Perrichon, *Ann. chim.*, [10], 5, 5-36 (1926).
- (8) Grard, *Compt. rend.*, 189, 541-3 (1929).
- (9) Koelsch, *J. Am. Chem. Soc.*, 54, 2045-8 (1932).
- (10) Vaughn, *J. Am. Chem. Soc.*, 55, 1293 (1933).
- (11) Vaughn, *J. Am. Chem. Soc.*, 55, 3453-8 (1933).
- (12) Ivanov and Spasov, *Arhiv. Hem. Farm.*, 8, 8-10 (1934); *Chem. Abstr.*, 28, 6711 (1934).
- (13) Dufraisse, Velluz, and Velluz, *Bull. soc. chim.*, [5], 4, 1260-4 (1937).
- (14) Oldham and Ubbelohde, *J. Chem. Soc.*, 1938, 201-6.
- (15) Whitmore, Wittle, and Harriman, *J. Am. Chem. Soc.*, 61, 1585-6 (1939).
- (16) Jacobs and Whitcher, *J. Am. Chem. Soc.*, 64, 2635-8 (1942).
- (17) Bachmann and Kloetzel, *J. Org. Chem.*, 3, 55-61 (1938).
- (18) Grard, *Ann. chim.*, [10], 13, 336-81 (1930).
- (19) Grignard and Tchéoufaki, *Compt. rend.*, 188, 357-61 (1929); *British Chem. Abstr.*, 1929A, 290.

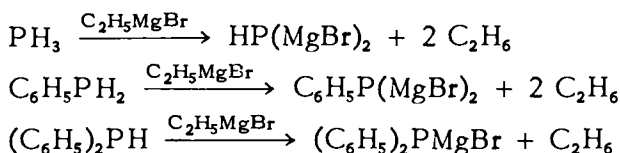
(i.e., when the Grignard reagent is capable of condensing with the corresponding halide) the better yields of "coupling product" (R_2) might be expected when the halogen solution is added slowly to the hot Grignard reagent solution.⁹

BORON COMPOUNDS

Reported reactions of boron compounds have been confined to those of the boric esters and boron trihalides. Apparently both the alkoxy groups of the esters and the halogen atoms of the trihalides are capable of successive replacement. However, the esters have been commonly employed for the preparation of organoboronic acids $[RB(OH)_2]$, and the trihalides for the preparation of trialkyl- or triarylborines (R_3B). Data are summarized in Table XXIII-II. The products reported are those obtained upon hydrolysis of the intermediates originally formed.

PHOSPHORUS COMPOUNDS

Phosphines. The phosphines, like their nitrogen analogs, react with Grignard reagents as "active hydrogen" compounds (Job and Desollier¹⁰).



Phosphorus trichloride. In one of several attempts to convert diphenylmagnesium to a phenylmagnesium halide Fleck¹¹ investigated the action

⁹ Cf., e.g., (a) Grignard and Perrichon, *Ann. chim.*, [10], 5, 5-36 (1926); (b) Grignard and Tchéoufaki, *Compt. rend.*, 188, 357-61 (1929); *British Chem. Abstr.*, 1929A, 290.

¹⁰ Job and Desollier, *Compt. rend.*, 184, 1454-6 (1927); *Chem. Abstr.*, 21, 3049 (1927).

¹¹ Fleck, *Ann.*, 276, 129-47 (1893).

TABLE XXIII-II

REACTIONS OF GRIGNARD REAGENTS WITH BORON COMPOUNDS

B Compound	RMgX	Product(s)	Ref.
BF ₃	CH ₃ MgBr	(CH ₃) ₃ B (87%)	11
BF ₃	C ₂ H ₅ MgBr	(C ₂ H ₅) ₃ B (74%, crude)	11
BF ₃	<i>n</i> -C ₃ H ₇ MgCl	(<i>n</i> -C ₃ H ₇) ₃ B (60%)*	3
BF ₃	<i>i</i> -C ₄ H ₉ MgCl	(<i>i</i> -C ₄ H ₉) ₃ B (<i>ca.</i> quant.)	3
BF ₃	<i>i</i> -C ₅ H ₁₁ MgCl	(<i>i</i> -C ₅ H ₁₁) ₃ B (60%)*	3
BF ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ B (50%)	4,5
BF ₃	(CH ₂) ₅ CHMgBr	[(CH ₂) ₅ CH] ₃ B (54%, crude)	7
BF ₃	C ₆ H ₅ CH ₂ MgCl	(C ₆ H ₅ CH ₂) ₃ B	8
BF ₃	4-CH ₃ C ₆ H ₄ MgBr	(4-CH ₃ C ₆ H ₄) ₃ B (50%, crude)	7
BF ₃	2,5-(CH ₃) ₂ C ₆ H ₃ MgBr	[2,5-(CH ₃) ₂ C ₆ H ₃] ₃ B (45%)	8
BF ₃	1-C ₁₀ H ₇ MgBr	(1-C ₁₀ H ₇) ₃ B	8
BCl ₃	C ₆ H ₅ MgBr	C ₆ H ₅ B(OH) ₂	2
B(OCH ₃) ₃	<i>n</i> -C ₃ H ₇ MgBr	<i>n</i> -C ₃ H ₇ B(OH) ₂ (54%, crude)	10
B(OCH ₃) ₃	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ B(OH) ₂ (60–70%, crude)	10
B(OCH ₃) ₃	<i>i</i> -C ₄ H ₉ MgBr	<i>i</i> -C ₄ H ₉ B(OH) ₂ (57%, crude)	10
B(OCH ₃) ₃	<i>n</i> -C ₅ H ₁₁ MgBr	<i>n</i> -C ₅ H ₁₁ B(OH) ₂ (70%, crude)	10
B(OCH ₃) ₃	C ₆ H ₅ MgBr	C ₆ H ₅ B(OH) ₂ + CH ₃ OH + CH ₃ C ₆ H ₅	1
B(OCH ₃) ₃	C ₆ H ₅ MgBr	C ₆ H ₅ B(OH) ₂ (86%) + CH ₃ OH	6
B(OCH ₃) ₃	<i>n</i> -C ₆ H ₁₃ MgBr	<i>n</i> -C ₆ H ₁₃ B(OH) ₂ (70%, crude)	10
B(OC ₂ H ₅) ₃	C ₆ H ₅ MgBr	C ₆ H ₅ B(OH) ₂	1
B(O- <i>n</i> -C ₃ H ₇) ₃	C ₆ H ₅ MgBr	C ₆ H ₅ B(OH) ₂	1
B(O- <i>n</i> -C ₄ H ₉) ₃	<i>n</i> -C ₁₄ H ₂₉ MgBr	<i>n</i> -C ₁₄ H ₂₉ B(OH) ₂	10
B(O- <i>i</i> -C ₄ H ₉) ₃	CH ₃ MgI	CH ₃ B(OH) ₂	1
B(O- <i>i</i> -C ₄ H ₉) ₃	RMgX [†]	RB(OH) ₂	1
B(O- <i>i</i> -C ₄ H ₉) ₃	4-BrC ₆ H ₄ MgBr	4-BrC ₆ H ₄ B(OH) ₂	9
B(O- <i>i</i> -C ₄ H ₉) ₃	2-ClC ₆ H ₄ MgBr	2-ClC ₆ H ₄ B(OH) ₂	9
B(O- <i>i</i> -C ₄ H ₉) ₃	C ₆ H ₅ MgBr	C ₆ H ₅ B(O- <i>i</i> -C ₄ H ₉) ₂ (50%)	1
B(O- <i>i</i> -C ₄ H ₉) ₃	C ₆ H ₅ CH ₂ MgCl	C ₆ H ₅ CH ₂ B(OH) ₂	1
B(O- <i>i</i> -C ₄ H ₉) ₃	2-CH ₃ C ₆ H ₄ MgBr	2-CH ₃ C ₆ H ₄ B(OH) ₂	9
B(O- <i>i</i> -C ₄ H ₉) ₃	3-CH ₃ C ₆ H ₄ MgBr	3-CH ₃ C ₆ H ₄ B(OH) ₂	1,9
B(O- <i>i</i> -C ₄ H ₉) ₃	4-CH ₃ C ₆ H ₄ MgBr	4-CH ₃ C ₆ H ₄ B(OH) ₂	9
B(O- <i>i</i> -C ₄ H ₉) ₃	2-CH ₃ OC ₆ H ₄ MgBr	2-CH ₃ OC ₆ H ₄ B(OH) ₂	9
B(O- <i>i</i> -C ₄ H ₉) ₃	3-CH ₃ OC ₆ H ₄ MgBr	3-CH ₃ OC ₆ H ₄ B(OH) ₂	9
B(O- <i>i</i> -C ₄ H ₉) ₃	4-CH ₃ OC ₆ H ₄ MgBr	4-CH ₃ OC ₆ H ₄ B(OH) ₂	9
B(O- <i>i</i> -C ₅ H ₁₁) ₃	C ₆ H ₅ MgBr	C ₆ H ₅ B(OH) ₂	1
B(OC ₆ H ₅) ₃	<i>n</i> -C ₃ H ₇ MgBr	B(<i>n</i> -C ₃ H ₇) ₃ (7%) + C ₆ H ₅ OH (56%)	6
B(OC ₆ H ₅) ₃	<i>n</i> -C ₄ H ₉ MgBr	B(<i>n</i> -C ₄ H ₉) ₃ (?) + C ₆ H ₅ OH (80%)	6
B(OC ₆ H ₅) ₃	C ₆ H ₅ MgBr	C ₆ H ₅ B(OH) ₂ (16.5%) + C ₆ H ₅ OH (40%)	6

* On basis of RX.

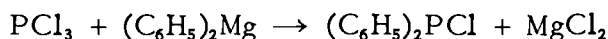
[†]R = C₂H₅, *n*-C₃H₇, *i*-C₄H₉, *i*-C₅H₁₁.

REFERENCES FOR TABLE XXIII-II

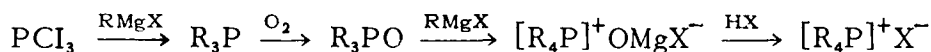
- (1) Khotinsky and Melamed, *Ber.*, 42, 3090–6 (1909).
- (2) Strecker, *Ber.*, 43, 1131–6 (1910).
- (3) Krause and Nitsche, *Ber.*, 54B, 2784–9 (1921).
- (4) Krause and Nitsche, *Ber.*, 55B, 1261–5 (1922).
- (5) Krause and Polack, *Ber.*, 59B, 777–85 (1926).
- (6) Gilman and Vernon, *J. Am. Chem. Soc.*, 48, 1063–6 (1926).

- (7) Krause and Polack, *Ber.*, 61B, 271-6 (1928).
 (8) Krause and Nobbe, *Ber.*, 63B, 934-42 (1930).
 (9) König and Scharnbeck, *J. prakt. Chem.*, [2], 128, 153-70 (1930).
 (10) Snyder, Kuck, and Johnson, *J. Am. Chem. Soc.*, 60, 105-11 (1938).
 (11) Brown, *J. Am. Chem. Soc.*, 67, 374-8 (1945).

on the magnesium compound of phosphorus trichloride. According to him the reaction apparently took the course:



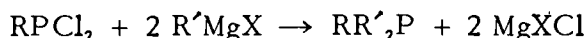
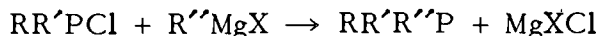
In general, phosphorus trichloride reacts with Grignard reagents to form trialkyl- or triarylphosphines. The trisubstituted phosphines are, however, readily oxidized to phosphine oxides by atmospheric oxygen. When this takes place, either accidentally or by design, in the presence of excess Grignard reagent, a phosphonium base, readily convertible by strong acid to a phosphonium salt, may be formed.



Thus, Augur and Billy¹² reported the products of reaction of phosphorus trichloride with excess methylmagnesium iodide as tetramethylphosphonium chloride and phosphorus diiodide (P_2I_4). Dodonov and Medox¹³ report a 73 percent yield of tetraphenylphosphonium bromide from treatment of a mixture of triphenylphosphine and phenylmagnesium bromide successively with oxygen, water, and hydrobromic acid. Willard *et al.*¹⁴ have prepared tetraphenylphosphonium bromide in 91 percent yield by adding phosphorus trichloride to an excess of phenylmagnesium bromide, and then treating the reaction mixture successively with atmospheric oxygen and aqueous hydrochloric acid.

When methylmagnesium iodide was slowly added to phosphorus trichloride, and the reaction mixture was then successively oxygenated and hydrolyzed, the products were dimethylphosphinic acid (principally), methylphosphoric acid, and trimethylphosphine oxide (Augur and Billy, *loc. cit.*¹²).

Monochloro and dichloro phosphine derivatives. The monochloro and dichloro phosphine derivatives, when added to an excess of Grignard reagent react in a manner analogous to that of phosphorus trichloride.



(For specific reactions and references see Table XXIII-III.) According to Grüttner and Wiernik,¹⁵ aryldichlorophosphines react with pentamethyl-

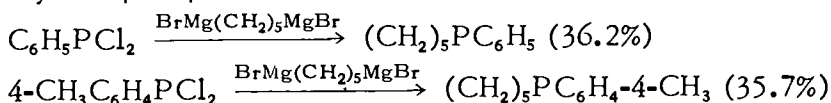
¹² Augur and Billy, *Compt. rend.*, 139, 597-9 (1904); *Chem. Zentr.*, 1904, 11, 1451.

¹³ Dodonov and Medox, *Ber.*, 61B, 907-11 (1928).

¹⁴ Willard, Perkins, and Blicke, *J. Am. Chem. Soc.*, 70, 737-8 (1948).

¹⁵ Grüttner and Wiernik, *Ber.*, 48, 1473-86 (1915).

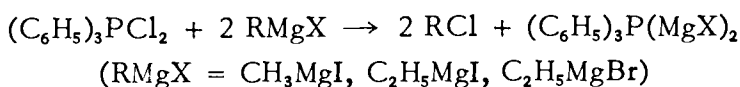
enemagnesium bromide to give yields of the order of 36 percent of aryl-pentamethylene phosphines.



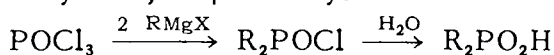
A similar reaction with tetramethylene magnesium bromide has been reported by Grüttner and Krause.¹⁶

Phosphorus pentachloride. Apparently three of the chlorine atoms of phosphorus pentachloride are more reactive toward Grignard reagents than the other two, for Grignard and Savard¹⁷ report triphenylphosphine chloride $[(\text{C}_6\text{H}_5)_3\text{PCl}_2]$ as the product of reaction with phenylmagnesium bromide. According to Kolutowska,¹⁸ triphenylphosphine and tetraphenylphosphonium bromide are byproducts of this reaction.

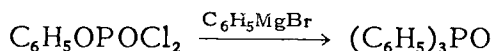
Grignard and Savard (*loc. cit.*¹⁷) report that triphenylphosphine chloride behaves as a chlorinating agent.



Phosphoryl chloride (POCl_3). When phosphoryl chloride is treated with three or more equivalents of Grignard reagent it yields a trisubstituted phosphine oxide. The reaction is probably stepwise, for Sauvage¹⁹ reports dibenzylphosphinic acid and di- α -naphthylphosphinic acid as byproducts of the preparations of tribenzylphosphine oxide and tri- α -naphthylphosphine oxide, respectively. By employing the reversed order of addition (so that phosphoryl chloride should always be present in excess), Kosolapoff²⁰ was able to prepare diphenylphosphinic and bis-*p*-chlorophenylphosphinic acids (in this article mis-named phosphonic acids) in 55 and 51 percent yields, respectively.



The possibility of "blocking" one of the chlorine atoms of phosphoryl chloride (*i.e.*, of replacing it by a readily hydrolyzable group) was investigated by Michaelis and Wegner.²¹ They found that substitution of a phenoxy group for a chlorine atom still permitted triple replacement by the Grignard reagent.



When, however, the piperidinamide corresponding to this phenyl ester was employed, satisfactory, though unspecified, yields of phosphinic acids

¹⁶ Grüttner and Krause, *Ber.*, 49, 437-44 (1916).

¹⁷ Grignard and Savard, *Compt. rend.*, 192, 592-5 (1931); *Chem. Abstr.*, 25, 2702 (1931).

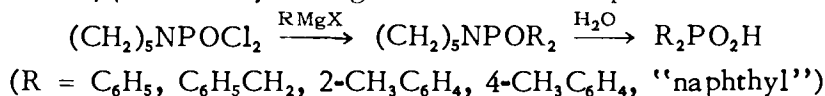
¹⁸ Kolutowska, *Roczniki Chem.*, 8, 568-75 (1928); *Chem. Abstr.*, 23, 2158 (1929).

¹⁹ Sauvage, *Compt. rend.*, 139, 674-6 (1904); *Chem. Zentr.*, 1904, II, 1638.

²⁰ Kosolapoff, *J. Am. Chem. Soc.*, 64, 2982-3 (1942).

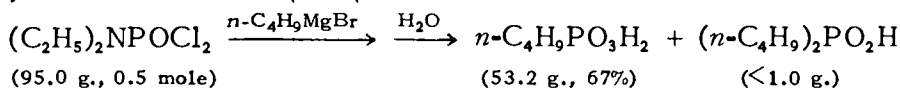
²¹ Michaelis and Wegner, *Ber.*, 48, 316-8 (1915).

were obtained, presumably through the reaction sequence:

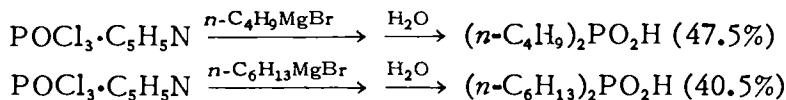


Kosolapoff²² has shown that the amide derived from the cheaper and more readily available diethylamine serves the purpose at least as well. His reported percentage yields of phosphinic acids from several Grignard reagents are as indicated: *n*-C₄H₉MgBr (82); 4-CH₃C₆H₄MgBr (75); 2-CH₃OC₆H₄MgBr (74); 4-CH₃OC₆H₄MgBr (79).

Kosolapoff²³ has found it possible, by operating at relatively low temperature (5–10°), to achieve a partial replacement of the chlorine of the diethylamide to obtain a phosphonic acid.

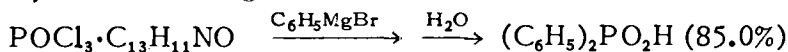


The feasibility of "blocking" a chlorine atom by quaternization with a tertiary base (specifically, pyridine) has also been investigated by Kosolapoff (*loc. cit.*²³). This expedient proved most effective when reversed addition was employed, but the yields obtained from the pyridine complex of phosphoryl chloride were inferior to those obtained from the diethylamide.

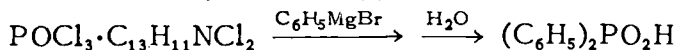


Similar "blocking" of a second chlorine atom, however, is apparently impossible, for the use of a second equivalent of pyridine led to the production of phosphinic acids only.

Kosolapoff's pyridine experiments suggest a more plausible explanation of the behavior of the *N*-methylacridone-phosphoryl chloride complex of Gleu and Schubert²⁴ than that embodied in the rather fantastic scheme proposed by those investigators:



or (in view of the biacrydilidene byproduct),



Phosphoric and phosphorous esters. According to Gilman *et al.*,²⁵ phosphoric and phosphorous esters behave toward aryl Grignard reagents very much like the corresponding chlorides (see Table XXIII-III). No trialkylphosphine oxide was isolated, however, when triphenyl phosphate was treated with *n*-propylmagnesium bromide nor when tri-*p*-tolyl phosphate was treated with benzylmagnesium chloride.

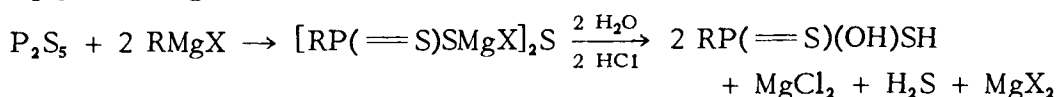
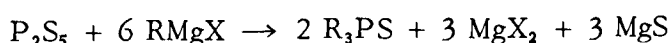
²² Kosolapoff, *J. Am. Chem. Soc.*, 71, 369–70 (1949).

²³ Kosolapoff, *J. Am. Chem. Soc.*, 72, 5508–9 (1950).

²⁴ Gleu and Schubert, *Ber.*, 73B, 805–11 (1940).

²⁵ (a) Gilman and Vernon, *J. Am. Chem. Soc.*, 48, 1063–6 (1926); (b) Gilman and Robinson, *Rec. trav. chim.*, 48, 328–31 (1929).

Phosphorus sulfides. According to Malatesta,²⁶ phosphorus pentasulfide reacts with excess (*ca.* 4 equiv.) Grignard reagent to yield dithiophosphonic acid, and trisubstituted phosphine sulfide. Some mercaptan (attributed to free sulfur) is also found. Malatesta and Pizzoti (*loc. cit.*^{26a}) believe that two principal reactions take place, as follows:



Other reactions of phosphorus sulfides are recorded in Table XXIII-III, as are reactions of various miscellaneous phosphorus compounds.

TABLE XXIII-III

REACTIONS OF GRIGNARD REAGENTS WITH PHOSPHORUS COMPOUNDS

P Compound	RMgX	Product(s)*	Ref.
PCl ₃	4 CH ₃ MgI	[(CH ₃) ₄ P] ⁺ Cl ⁻ + P ₂ I ₄	2
PCl ₃ (excess)	CH ₃ MgBr (+ O ₂)	(CH ₃) ₂ PO(OH) (chief product) + (CH ₃) ₃ PO + CH ₃ PO(OH) ₂	2
PCl ₃	C ₂ H ₅ MgBr	(C ₂ H ₅) ₃ P (70%)	4
PCl ₃	H ₂ C=CHCH ₂ MgBr	(H ₂ C=CHCH ₂) ₃ P	29
PCl ₃	<i>n</i> -C ₃ H ₇ MgBr	(<i>n</i> -C ₃ H ₇) ₃ P (58%)	16
PCl ₃	<i>n</i> -C ₄ H ₉ MgBr	(<i>n</i> -C ₄ H ₉) ₃ P (54%)	15
PCl ₃	<i>i</i> -C ₄ H ₉ MgBr	(<i>i</i> -C ₄ H ₉) ₃ P (47%)	16
PCl ₃	2-Pyridyl-MgBr	(α-C ₅ H ₄ N) ₃ P	24, 30
PCl ₃	<i>n</i> -C ₅ H ₁₁ MgBr	(<i>n</i> -C ₅ H ₁₁) ₃ P (39%)	16
PCl ₃	<i>i</i> -C ₅ H ₁₁ MgBr	(<i>i</i> -C ₅ H ₁₁) ₃ P (39%)	16
PCl ₃	CH ₃ (C ₂ H ₅)CHCH ₂ MgBr	[CH ₃ (C ₂ H ₅)CHCH ₂] ₃ P ("poor yield")	16
PCl ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ P (19-22%)	1, 3
PCl ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ P (90%, crude; 76%, pure)	12
PCl ₃	C ₆ H ₅ MgBr (+ O ₂)	[(C ₆ H ₅) ₄ P] ⁺ Br ⁻ (91%)	26
PCl ₃	Indolyl-MgBr	(β-C ₈ H ₆ N) ₃ P + (N-C ₈ H ₆ N) ₃ P	18
PCl ₃	α-Methylindolyl-MgBr	(β-C ₉ H ₆ N) ₃ P + (N-C ₉ H ₆ N) ₃ P	18
4-BrC ₆ H ₄ PCl ₂	H ₂ C=CHCH ₂ MgBr	4-BrC ₆ H ₄ P(CH ₂ CH=CH ₂) ₂ (56%)	29
C ₆ H ₅ PCl ₂	CH ₃ MgI	C ₆ H ₅ P(CH ₃) ₂ (35%)	13, 11
C ₆ H ₅ PCl ₂	C ₂ H ₅ MgBr	C ₆ H ₅ P(C ₂ H ₅) ₂	11

* The products reported are those obtained after hydrolysis of the reaction mixture.

²⁶(a) Malatesta and Pizzoti, *Gazz. chim. ital.*, 76, 167-81 (1946); *Chem. Abstr.*, 41, 2012 (1947); (b) Malatesta, *Gazz. chim. ital.*, 77, 509-17 (1947); *Chem. Abstr.*, 42, 5411 (1948).

TABLE XXIII-III (Continued)

P Compound	RMgX	Product(s)*	Ref.
$C_6H_5PCl_2$	$H_2C=CHCH_2MgBr$	$C_6H_5P(CH_2CH=CH_2)_2$ (34%)	29
$C_6H_5PCl_2$	$n-C_3H_7MgBr$	$C_6H_5P(n-C_3H_7)_2$ (58%)	16
C_6H_5PCl	$H_2C=C(CH_3)CH_2MgBr$	$C_6H_5P[CH_2CH(CH_3)=CH_2]_2$ (56%)	29
$C_6H_5PCl_2$	$BrMg(CH_2)_4MgBr$	$C_6H_5P(CH_2)_4$ (31-35%)	9
$C_6H_5PCl_2$	$n-C_4H_9MgBr$	$C_6H_5P(n-C_4H_9)_2$ (52%)	15
$C_6H_5PCl_2$	$i-C_4H_9MgBr$	$C_6H_5P(i-C_4H_9)_2$ (56%)	16
$C_6H_5PCl_2$	2-Pyridyl-MgBr	$C_6H_5P(\alpha-C_5H_4N)_2$	30
$C_6H_5PCl_2$	$BrMg(CH_2)_5MgBr$	$C_6H_5P(CH_2)_5$ (36%)	7
$C_6H_5PCl_2$	$n-C_5H_{11}MgBr$	$C_6H_5P(n-C_5H_{11})_2$ (57%)	16
$C_6H_5PCl_2$	$i-C_5H_{11}MgBr$	$C_6H_5P(i-C_5H_{11})_2$ (47%)	16
$C_6H_5PCl_2$	$CH_3(C_2H_5)CHCH_2MgBr$	$C_6H_5P[CH_2CH(CH_3)C_2H_5]_2$ (31%)	16
$C_6H_5PCl_2$	$i-C_6H_{13}MgBr$	$C_6H_5P(i-C_6H_{13})_2$ (27%)	16
$4-CH_3C_6H_4PCl_2$	C_2H_5MgBr	$4-CH_3C_6H_4P(C_2H_5)_2$	24
$4-CH_3C_6H_4PCl_2$	$H_2C=CHCH_2MgBr$	$4-CH_3C_6H_4P(CH_2CH=CH_2)_2$ (27%)	29
$4-CH_3C_6H_4PCl_2$	$n-C_3H_7MgBr$	$4-CH_3C_6H_4P(n-C_3H_7)_2$ (50%)	16
$4-CH_3C_6H_4PCl_2$	$n-C_4H_9MgBr$	$4-CH_3C_6H_4P(n-C_4H_9)_2$ (47%)	15
$4-CH_3C_6H_4PCl_2$	$i-C_4H_9MgBr$	$4-CH_3C_6H_4P(i-C_4H_9)_2$ (25%)	16
$4-CH_3C_6H_4PCl_2$	$BrMg(CH_2)_5MgBr$	$4-CH_3C_6H_4P(CH_2)_5$ (36%)	7
$4-CH_3C_6H_4PCl_2$	$n-C_5H_{11}MgBr$	$4-CH_3C_6H_4P(n-C_5H_{11})_2$ (56%)	16
$4-CH_3C_6H_4PCl_2$	$i-C_5H_{11}MgBr$	$4-CH_3C_6H_4P(i-C_5H_{11})_2$	16
$4-CH_3C_6H_4PCl_2$	$CH_3(C_2H_5)CHCH_2MgBr$	$4-CH_3C_6H_4P[CH_2CH(CH_3)C_2H_5]_2$ (34%)	16
$4-CH_3C_6H_4PCl_2$	$i-C_6H_{13}MgBr$	$4-CH_3C_6H_4P(i-C_6H_{13})_2$	16
$4-CH_3OC_6H_4PCl_2$	$H_2C=CHCH_2MgBr$	$4-CH_3OC_6H_4P(CH_2CH=CH_2)_2$ (43%)	29
$4-CH_3OC_6H_4PCl_2$	$n-C_3H_7MgBr$	$4-CH_3OC_6H_4P(n-C_3H_7)_2$ (47%)	19
$4-CH_3OC_6H_4PCl_2$	$n-C_4H_9MgBr$	$4-CH_3OC_6H_4P(n-C_4H_9)_2$ (38%)	19
$4-CH_3OC_6H_4PCl_2$	$n-C_5H_{11}MgBr$	$4-CH_3OC_6H_4P(n-C_5H_{11})_2$ (34%)	19
$4-C_2H_5C_6H_4PCl_2$	$H_2C=CHCH_2MgBr$	$4-C_2H_5C_6H_4P(CH_2CH=CH_2)_2$ (56%)	29
$4-C_2H_5C_6H_4PCl_2$	$n-C_3H_7MgBr$	$4-C_2H_5C_6H_4P(n-C_3H_7)_2$ (44%)	19
$4-C_2H_5C_6H_4PCl_2$	$n-C_4H_9MgBr$	$4-C_2H_5C_6H_4P(n-C_4H_9)_2$ (36%)	19
$4-C_2H_5C_6H_4PCl_2$	$n-C_5H_{11}MgBr$	$4-C_2H_5C_6H_4P(n-C_5H_{11})_2$ (35%)	19
2,5- (CH_3) ₂ $C_6H_3PCl_2$	CH_3MgI	2,5-(CH_3) ₂ $C_6H_3P(CH_3)_2$ (ca. 64%)	20

* The products reported are those obtained after hydrolysis of the reaction mixture.

TABLE XXIII-III (Continued)

P Compound	RMgX	Product(s)*	Ref.
2,5- (CH ₃) ₂ C ₆ H ₃ PCl ₂	C ₂ H ₅ MgBr	2,5-(CH ₃) ₂ C ₆ H ₃ P(C ₂ H ₅) ₂ (74%)	20
2,5- (CH ₃) ₂ C ₆ H ₃ PCl ₂	<i>n</i> -C ₃ H ₇ MgBr	2,5-(CH ₃) ₂ C ₆ H ₃ P(<i>n</i> -C ₃ H ₇) ₂ (64%)	20
2,5- (CH ₃) ₂ C ₆ H ₃ PCl ₂	<i>n</i> -C ₄ H ₉ MgBr	2,5-(CH ₃) ₂ C ₆ H ₃ P(<i>n</i> -C ₄ H ₉) ₂ (64%)	20
2,5- (CH ₃) ₂ C ₆ H ₃ PCl ₂	<i>i</i> -C ₄ H ₉ MgBr	2,5-(CH ₃) ₂ C ₆ H ₃ P(<i>i</i> -C ₄ H ₉) ₂	20
2,5- (CH ₃) ₂ C ₆ H ₃ PCl ₂	<i>n</i> -C ₅ H ₁₁ MgBr	2,5-(CH ₃) ₂ C ₆ H ₃ P(<i>n</i> -C ₅ H ₁₁) ₂	20
H ₂ C= C(CH ₃)C ₆ H ₄ PCl ₂	H ₂ C=CHCH ₂ MgBr	H ₂ C=C(CH ₃)C ₆ H ₄ P- (CH ₂ C=CH ₂) ₂ (53%)	29
4-C ₆ H ₅ OC ₆ H ₄ PCl ₂	H ₂ C=CHCH ₂ MgBr	4-C ₆ H ₅ OC ₆ H ₄ P(CH ₂ CH= CH ₂) ₂ (<i>ca.</i> 28%)	29
(C ₂ H ₅) ₂ PCl	2-CH ₃ OCH ₂ C ₆ H ₄ CH ₂ CH ₂ MgCl	(C ₂ H ₅) ₂ PCH ₂ CH ₂ C ₆ H ₄ -2- CH ₂ OCH ₃ (74%)	32
(C ₂ H ₅) ₂ PCl	2-CH ₃ O(CH ₂) ₃ C ₆ H ₄ MgBr	(C ₂ H ₅) ₂ PC ₆ H ₄ -2- (CH ₂) ₃ OCH ₃ (73%)	32
4-BrC ₆ H ₄ (C ₆ H ₅)PCl	C ₂ H ₅ MgBr	4-BrC ₆ H ₄ (C ₆ H ₅)PC ₂ H ₅	24
4-BrC ₆ H ₄ (C ₆ H ₅)PCl	2-Pyridyl-MgBr	4-BrC ₆ H ₄ (C ₆ H ₅)P(α - C ₅ H ₄ N)	24
4-BrC ₆ H ₄ (C ₆ H ₅)PCl	3-Pyridyl-MgBr	4-BrC ₆ H ₄ (C ₆ H ₅)P(β - C ₅ H ₄ N)	24
4-BrC ₆ H ₄ (C ₆ H ₅)PCl	4-CH ₃ OC ₆ H ₄ MgBr	4-BrC ₆ H ₄ (C ₆ H ₅)PC ₆ H ₄ -4- OCH ₃	24
4-BrC ₆ H ₄ (C ₆ H ₅)PCl	4-(CH ₃) ₂ NC ₆ H ₄ MgBr	4-BrC ₆ H ₄ (C ₆ H ₅)PC ₆ H ₄ -4- N(CH ₃) ₂ (37%)	24
(C ₆ H ₅) ₂ PCl	CH ₃ MgX	(C ₆ H ₅) ₂ PCH ₃ (70%)	11
(C ₆ H ₅) ₂ PCl	C ₂ H ₅ MgBr	(C ₆ H ₅) ₂ PC ₂ H ₅ (70%)	11
(C ₆ H ₅) ₂ PCl	2-Pyridyl-MgBr	(C ₆ H ₅) ₂ P(α -C ₅ H ₄ N) (20%)	30
(C ₆ H ₅) ₂ PCl	C ₆ H ₅ CH ₂ MgCl	(C ₆ H ₅) ₂ PCH ₂ C ₆ H ₅	11
C ₆ H ₅ (4- CH ₃ OC ₆ H ₄)PCl	C ₂ H ₅ MgBr	C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)PC ₂ H ₅	24
C ₆ H ₅ (4- CH ₃ OC ₆ H ₄)PCl	<i>n</i> -C ₃ H ₇ MgBr	C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)P- <i>n</i> - C ₃ H ₇	24
C ₆ H ₅ (4- CH ₃ OC ₆ H ₄)PCl	<i>n</i> -C ₄ H ₉ MgBr	C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)P- <i>n</i> - C ₄ H ₉ (70%)	24
C ₆ H ₅ (4- CH ₃ OC ₆ H ₄)PCl	4-CH ₃ C ₆ H ₄ MgBr	C ₆ H ₅ (4-CH ₃ OC ₆ H ₄)PC ₆ H ₄ - 4-CH ₃	24
PCl ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ P + (C ₆ H ₅) ₃ PCl ₂ + [(C ₆ H ₅) ₄ P] ⁺ Br ⁻	14
PCl ₅	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ PCl ₂	21
POCl ₃	RMgX [†]	R ₃ PO	5
POCl ₃	H ₂ C=C(CH ₃)CH ₂ MgBr	[H ₂ C=C(CH ₃)CH ₂] ₃ PO	29
POCl ₃	4-ClC ₆ H ₄ MgBr [‡]	(4-ClC ₆ H ₄) ₂ PO(OH) (51%) + (4-ClC ₆ H ₄) ₃ PO (7%)	23
POCl ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ PO	3,5, 21

* The products reported are those obtained after hydrolysis of the reaction mixture.

[†] R = CH₃, C₂H₅, *n*-C₃H₇, C₆H₅, C₆H₅CH₂.

[‡] Reversed order of addition.

TABLE XXIII-III (Continued)

P Compound	RMgX	Product(s)*	Ref.
POCl ₃	C ₆ H ₅ MgBr [†]	(C ₆ H ₅) ₂ PO(OH) (55%) + (C ₆ H ₅) ₃ PO (7%)	23
POCl ₃	C ₆ H ₅ CH ₂ MgCl	(C ₆ H ₅ CH ₂) ₃ PO + (C ₆ H ₅ CH ₂) ₂ PO(OH)	3
POCl ₃	1-C ₁₀ H ₇ MgBr	(1-C ₁₀ H ₇) ₃ PO + (1-C ₁₀ H ₇) ₂ PO(OH)	3
PSCl ₃	CH ₃ MgI	[(CH ₃) ₂ PS] ₂ (?)	33
PSCl ₃	C ₂ H ₅ MgBr (excess)	(C ₂ H ₅) ₂ PS(OH)	8
PSCl ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ PS	8
PSCl ₃	C ₆ H ₅ CH ₂ MgCl	(C ₆ H ₅ CH ₂) ₃ PS + (C ₆ H ₅ CH ₂) ₂ PS(OH)	8
C ₆ H ₁₃ NO·POCl ₃ [‡]	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ PO(OH) (85%)	22
C ₅ H ₅ N·POCl ₃ [§]	<i>n</i> -C ₄ H ₉ MgBr	(<i>n</i> -C ₄ H ₉) ₂ PO(OH) (47.5%)	34
C ₅ H ₅ N·POCl ₃ [§]	<i>n</i> -C ₆ H ₁₃ MgBr	(<i>n</i> -C ₆ H ₁₃) ₂ PO(OH) (40.5%)	34
C ₆ H ₅ OPOCl ₂	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ PO	6
(C ₂ H ₅) ₂ NPOCl ₂	<i>n</i> -C ₄ H ₉ MgBr	(<i>n</i> -C ₄ H ₉) ₂ PO(OH) (82%)	31
(C ₂ H ₅) ₂ NPOCl ₂	<i>n</i> -C ₄ H ₉ MgBr	<i>n</i> -C ₄ H ₉ PO(OH) ₂ (67%) + (<i>n</i> -C ₄ H ₉) ₂ PO(OH) (trace) [¶]	34
(C ₂ H ₅) ₂ NPOCl ₂	4-CH ₃ C ₆ H ₄ MgBr	(4-CH ₃ C ₆ H ₄) ₂ PO(OH) (75%)	31
(C ₂ H ₅) ₂ NPOCl ₂	2-CH ₃ OC ₆ H ₄ MgBr	(2-CH ₃ OC ₆ H ₄) ₂ PO(OH) (74%)	31
(C ₂ H ₅) ₂ NPOCl ₂	4-CH ₃ OC ₆ H ₄ MgBr	(4-CH ₃ OC ₆ H ₄) ₂ PO(OH) (79%)	31
(CH ₂) ₅ NPOCl ₂	RMgX [‡]	R ₂ PO(OH)	6
P(OCH ₃) ₃	C ₆ H ₅ MgBr (excess)	CH ₃ O(C ₆ H ₅) ₂ PO (42%)	17
P(OC ₂ H ₅) ₃	C ₆ H ₅ MgBr (excess)	(C ₆ H ₅) ₃ PO (10%)	17
P(OC ₆ H ₅) ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ P (60%) + C ₆ H ₅ OH (68%)	10
PO(OCH ₃) ₃	C ₆ H ₅ MgBr	"No toluene"	17
PO(OC ₂ H ₅) ₃	C ₆ H ₅ MgBr	C ₆ H ₅ PO(OC ₂ H ₅) ₂ (16%) + (C ₆ H ₅) ₂ PO(OH) (17%)	17
PO(OC ₆ H ₅) ₃	<i>n</i> -C ₃ H ₇ MgBr	C ₆ H ₅ OH (49%) + unidentified product	10
PO(OC ₆ H ₅) ₃	4 C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ PO (17%) + C ₆ H ₅ OH (49%)	10
PO(OC ₆ H ₄ -4-CH ₃) ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ PO (50%) + 4- CH ₃ C ₆ H ₄ OH (54%)	10
PO(OC ₆ H ₄ -4-CH ₃) ₃	C ₆ H ₅ CH ₂ MgCl	4-CH ₃ C ₆ H ₄ OH (28%) + unidentified product	10
C ₆ H ₅ PO(OC ₂ H ₅) ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ PO(OH) (32.5%)	34
P ₂ I ₄	CH ₃ MgI	[(CH ₃) ₄ P] ⁺ I ⁻	2

* The products reported are those obtained after hydrolysis of the reaction mixture.

[†] Reversed order of addition.

[‡] The complex from *N*-methylacridone and phosphoryl chloride; possibly C₆H₁₃NCl₂·POCl₃; probably a quaternary salt.

[§] The complex from pyridine and phosphoryl chloride; probably a quaternary salt.

[¶] Low-temperature (5–10°) reaction.

[‡] R = C₆H₅, C₆H₅CH₂, 2-CH₃C₆H₄, 4-CH₃C₆H₄, 1-C₁₀H₇.

TABLE XXIII-III (Continued)

P Compound	RMgX	Product(s)*	Ref.
P ₂ S ₅	CH ₃ MgI	(CH ₃) ₃ PS + (CH ₃) ₂ PS(SH) + CH ₃ PS(OH)SH (?)	27
P ₂ S ₅	RMgBr [†]	RPS(OH)SH + RPS(SH) + R ₃ PS + RSH	25
P ₂ S ₅	<i>i</i> -C ₄ H ₉ MgBr	(<i>i</i> -C ₄ H ₉) ₃ P + (<i>i</i> -C ₄ H ₉) ₂ PS(SH)	27
P ₂ S ₅	(CH ₂) ₅ CHMgBr	[(CH ₂) ₅ CH] ₃ P (?) + [(CH ₂) ₅ CH] ₂ PS(SH) + (CH ₂) ₅ CHPS(OH)SH	27
P ₃ S ₆	C ₂ H ₅ MgBr	(C ₂ H ₅) ₃ P + (C ₂ H ₅) ₃ PS	28
P ₃ S ₆	C ₆ H ₅ MgBr	(C ₆ H ₅) ₃ P + (C ₆ H ₅) ₃ PS + phenylthiophosphonic acids	28
P ₄ S ₃	C ₂ H ₅ MgBr	(C ₂ H ₅) ₂ PH (21%) + (C ₂ H ₅) ₃ P (6%)	28
P ₄ S ₃	C ₆ H ₅ MgBr	(C ₆ H ₅) ₂ PH (24%)	28
P ₄ S ₇	C ₂ H ₅ MgBr	(C ₂ H ₅) ₃ P (<i>ca.</i> 40%) + ethylthiophosphinic acids	28

* The products reported are those obtained after hydrolysis of the reaction mixture.

[†]R = C₂H₅, *i*-C₃H₇, C₆H₅.

REFERENCES FOR TABLE XXIII-III

- (1) Pfeiffer, Heller, and Pietsch, *Ber.*, 37, 4620-3 (1904).
- (2) Auger and Billy, *Compt. rend.*, 139, 597-9 (1904); *Chem. Zentr.*, 1904,II, 1451.
- (3) Sauvage, *Compt. rend.*, 139, 674-6 (1904); *Chem. Zentr.*, 1904,II, 1638.
- (4) Hibbert, *Ber.*, 39, 160-2 (1906).
- (5) Pickard and Kenyon, *J. Chem. Soc.*, 89, 262-73 (1906).
- (6) Michaelis and Wagner, *Ber.*, 48, 316-8 (1915).
- (7) Grüttner and Wiernik, *Ber.*, 48, 1473-86 (1915).
- (8) Strecker and Grossmann, *Ber.*, 49, 63-87 (1916).
- (9) Grüttner and Krause, *Ber.*, 49, 437-44 (1916).
- (10) Gilman and Vernon, *J. Am. Chem. Soc.*, 48, 1063-6 (1926).
- (11) Meisenheimer, Casper, Horing, Lauter, Lichtenstadt, and Samuel, *Ann.*, 449, 213-48 (1926).
- (12) Dodonov and Medox, *Ber.*, 61B, 907-11 (1928).
- (13) Ingold, Shaw, and Wilson, *J. Chem. Soc.*, 1928, 1280-6.
- (14) Kolutowska, *Roczniki Chem.*, 8, 568-75 (1928); *Chem. Abstr.*, 23, 2158 (1929).
- (15) Davies and Jones, *J. Chem. Soc.*, 1929, 33-5.
- (16) Davies, Pearse, and Jones, *J. Chem. Soc.*, 1929, 1262-8.
- (17) Gilman and Robinson, *Rec. trav. chim.*, 48, 328-31 (1929).
- (18) Mingoia, *Gazz. chim. ital.*, 60, 144-9 (1930); *Chem. Zentr.*, 1930,I, 3473; *Chem. Abstr.*, 24, 3783 (1930).
- (19) Jackson, Davies, and Jones, *J. Chem. Soc.*, 1930, 2298-301.
- (20) Jackson and Jones, *J. Chem. Soc.*, 1931, 575-8.
- (21) Grignard and Savard, *Compt. rend.*, 192, 592-5 (1931); *Chem. Abstr.*, 25, 2702 (1931).

- (22) Gleu and Schubert, *Ber.*, 73B, 805-11 (1940).
- (23) Kosolapoff, *J. Am. Chem. Soc.*, 64, 2982-3 (1942).
- (24) Davies and Mann, *J. Chem. Soc.*, 1944, 276-83.
- (25) Malatesta and Pizzoti, *Gazz. chim. ital.*, 76, 167-81 (1946); *Chem. Abstr.*, 41, 2012 (1947).
- (26) Willard, Perkins, and Blicke, *J. Am. Chem. Soc.*, 70, 737-8 (1948).
- (27) Malatesta, *Gazz. chim. ital.*, 77, 509-17 (1947); *Chem. Abstr.*, 42, 5411 (1948).
- (28) Malatesta, *Gazz. chim. ital.*, 77, 518-25 (1947); *Chem. Abstr.*, 42, 5413 (1948).
- (29) Jones, Davies, Bowden, Edwards, Davis, and Thomas, *J. Chem. Soc.*, 1947, 1446-50.
- (30) Mann and Watson, *J. Org. Chem.*, 13, 502-31 (1948).
- (31) Kosolapoff, *J. Am. Chem. Soc.*, 71, 369-70 (1949).
- (32) Beeby and Mann, *J. Chem. Soc.*, 1951, 411-5.
- (33) Kabachnik and Shepeleva, *Izvest. Akad. Nauk S.S.S.R., Otdel. Khim. Nauk*, 1949, No. 1, 56-9; *Chem. Abstr.*, 43, 5739 (1949).
- (34) Kosolapoff, *J. Am. Chem. Soc.*, 72, 5508-9 (1950).

Index of Grignard Reagents

As is obvious upon inspection, the following index is self-ordered on the basis of empirical formulae. It is designed to answer for the referent questions that fall into four general categories.

1. Is there a published claim that a given Grignard reagent has been prepared or must have been present in a Barbier-type synthesis? [Presence in the index constitutes an affirmative answer. Where the evidence supporting the claim appears insufficient or questionable, or where reports of other investigators cast doubt upon the claim, the present authors have appended a question mark (?). Where the original investigator's designation of a Grignard reagent leaves doubt as to its precise identity, that designation is placed in quotation marks. Where the constitution of a Grignard reagent is uncertain or indeterminate, an explanatory footnote is appended. More or less arbitrary conventional representations of structural units in formulae that might prove unintelligible or ambiguous to the average referent are also explained in footnotes. Absence of a given Grignard reagent from the index *may* be the result of oversight, or an inevitable consequence of post-publication-deadline report.]

2. Is there in the present text a description of, or reference to a published description of, the preparation of an indexed Grignard reagent? [Affirmative answers are indicated by page-number references in Arabic numerals set in *italic* type. Incidentally, not all preparations described constitute good preparative methods.]

3. Is there in the present text discussion or mention of: (a) unique or special properties, or (b) unique or special uses, or (c) uses in significant experiments, of an indexed Grignard reagent? [Affirmative answers are indicated by page-number references in Arabic numerals set in Roman type. Mentions of nonspecific uses of individual Grignard reagents are not, in general, indexed.]

4. Are there published reports of reactions of an indexed Grignard reagent with the one or more of the more generally-used Grignard-reagent co-reactants? [Affirmative answers are indicated by appropriate table-number references in Roman numerals set in Roman type. Absence of tabular record *may* be due to oversight, or to recency of report.]

CH₂H₂C(MgI)₂ (?), 32**CH₃**CH₃MgCl, 25-26, 32, VI-V, VI-XVII, VI-XVIII, VI-XIX, VIII-III, IX-II, XVI-I, XVII-IV, 1173, XVIII-I, XIX-I, XXII-ICH₃MgBr, 32, 131, V-I, VI-V, VI-VI, VI-IX, VI-XVII, VI-XVIII, VI-XIX, VII-II, VIII-III, IX-I, IX-II, X-I, XI-I, XII-I, XIII-II, XIV-I, 1052, 1059, XVI-I, XVII-IV, XVIII-I, XXI-VII, XXII-I, XXIII-II, XXIII-IIIC¹⁴H₃MgBr, IX-ICH₃MgI, 32, 105, 107, 131, VI-I, VI-IV, VI-V, VI-VI, VI-VII, VI-XI, VI-XVII, VI-XVIII, VI-XIX, VII-II, 564, 568, 575, VIII-III, VIII-IV, IX-I, IX-II, X-I, XI-I, XII-I, XIII-I, XIII-II, XIV-I, 1052, 1055-1056, XVI-I, XVII-IV, XVIII-I, XIX-I, XIX-II, XIX-III, XIX-VIII, XX-II, XXI-IV, XXI-VI, XXI-VII, XXII-I, XXIII-II, XXIII-IIIC¹⁴H₃MgI, IX-I, XVI-ICH₃MgX, VI-X(CH₃)₂Mg, 1, 3, 91, 105, XIV-I, 1172-1173, XVIII-I**C₂**(≡CMgBr)₂, 67-68, VI-XVII, VI-XVIII, VI-XIX, VIII-III, X-I, XIII-I, XVI-I, XIX-III, XX-II, XXIII-I(≡CMgI)₂, 68, VI-XVII, VI-XVIII, VI-XIX**C₂H**

HC≡CMgBr, 68-69, 70, VI-XVII, VI-XVIII, VI-XIX, X-I, XIII-I, XVI-I, XX-II, XXII-I

C₂H₅C₂H₅MgCl, 26, 32, 105, VI-XVIII, VIII-III, XIV-I, XVI-I, XVIII-I, XIX-I, XIX-XII, XX-I, XXI-VII, XXII-IC₂H₅MgBr, 10, 11, 19, 25, 30, 32, 47, 49, 52, 53, 56, 104, 105, 109, 123, V-I, VI-I, VI-IX, VI-XVII, VI-XVIII, VI-XIX, VII-II, 575, VIII-III, VIII-IV, IX-I, IX-II, X-I, XI-I, XII-I, XIII-I, XIII-II, XIV-I, 1059, XVI-I, XVII-IV, XVIII-I, XIX-I, XIX-II, XIX-III, XIX-VI, XIX-VIII, XIX-XII, XIX-XV, XX-I, XX-II, XXI-II, XXI-IV, XXI-V, XXI-VI, XXI-VII, XXII-I, XXIII-I, XXIII-II, XXIII-IIIC¹⁴H₅CH₃MgBr, X-ICH₃C¹⁴H₅MgBr, X-IC₂H₅MgI, 17, 19, 32, 49, 52, 53, 92, 104, 105, 131, V-I, VI-V, VI-XVII, VI-XVIII, VI-XIX, VII-II, 564, VIII-III, IX-II, X-I, XI-I, XII-I, XIII-II,**C₂H₅ (cont.)**XIV-I, XVI-I, XVIII-I, XIX-I, XIX-II, XIX-III, XIX-VIII, XIX-XII, XX-II, XXI-II, XXI-VII, XXII-I, XXIII-I
(C₂H₅)₂Mg, 1, 2, 105, 106-107, XIV-I, XVI-I**C₂H₅O**CH₃OCH₂MgBr, XVI-I**C₃F₇**C₃F₇MgBr, * 34C₃F₇MgI, † 34**C₃H₂O**BrMgOCH₂C≡CMgBr, VI-XIX**C₃H₃**HC≡CCH₂MgBr, VIII-III, XIII-ICH₃C≡CMgBr, VI-XVIII, VIII-III, XII-I, XIII-I, XIV-I**C₃H₃N₂**

Imidazolyl-MgBr, 84-85

Pyrazolyl-MgBr, 85-86, XI-I

C₃H₄F₃F₃CCH₂CH₂MgCl, 34, XIII-I, XX-II**C₃H₅**H₂C=CHCH₂MgCl, 18, 27, VI-XVII, VI-XVIII, VI-XIX, XVI-I, XVII-IV, XXII-IH₂C=CHCH₂MgBr, 17, 24, 47-48, VI-I, VI-XVII, VI-XVIII, VI-XIX, VIII-III, X-I, XI-I, XIII-I, XIV-I, 1051, XVI-I, XVII-IV, XIX-III, XIX-VIII, XXII-I, XXIII-III**C₃H₅O₂**H₃CO₂CCH₂MgCl, VIII-III**C₃H₇***n*-C₃H₇MgCl, 26, 32, 92, 105, VI-XVII, VI-XVIII, VIII-III, VIII-IV, IX-II, X-I, XIV-I, XVI-I, XVII-IV, XIX-I, XIX-XI, XXII-I, XXIII-II*n*-C₃H₇MgBr, 19, 25, 32, 47, 49, 92, 105, V-I, VI-I, VI-VIII, VI-IX, VI-XVII, VI-XVIII, VI-XIX, VII-II, VIII-III, VIII-IV, IX-I, IX-II, X-I, XI-I, XII-I, XIII-I, XIV-I, 1059, XVI-I, XVII-IV, XVIII-I, XIX-I, XIX-II, XXI-IV, XXI-V, XXII-I, XXIII-I, XXIII-III*n*-C₃H₇MgI, 32, 52, 105, VI-XVIII, VIII-III, X-I, XII-I, XIII-II, XIV-I, XVI-I, XIX-II, XXI-II(n-C₃H₇)₂Mg, 1, 105*i*-C₃H₇MgCl, 26, 32, VI-XVII, VI-XVIII, VI-XIX, VIII-III, IX-II, X-I, XIV-I, XVI-I, XIX-I, XIX-XII, XXII-I*i*-C₃H₇MgBr, 19, 30, 32, 47, 49, V-I, VI-VIII, VI-IX, VI-XVII, VI-XVIII,

*From "heptafluorobromopropane."

†From "heptafluoroiodopropane."

C₃H₇ (cont.)

VI-XIX, VIII-III, VIII-IV, IX-I, 726, 727, IX-II, X-I, XI-I, XIII-I, XIII-II, XIV-I, 1059, XVI-I, XVII-IV, XIX-I, XIX-II, XXIII-I
i-C₃H₇MgI, 32, VI-XIX, X-I, XI-I, XIV-I, XXIII-I

C₃H₇O₂

H₃CO₂CCH₂MgBr, VI-XIX

C₄H₂BrS

5-Bromo-2-thienyl-MgBr, VIII-III

C₄H₂IO

5-Iodo-2-furyl-MgI, XXI-I

C₄H₃

H₂C=CHC≡CMgBr, VI-XVII, VI-XVIII, VIII-III, XI-I, XIII-I, XIV-I, XVI-I, XXI-I

C₄H₃O

2-Furyl-MgBr, VI-XIX, VII-II, XIII-I, XIX-I

2-Furyl-MgI, VI-XVII, VIII-III, IX-II

C₄H₃S

2-Thienyl-MgBr, VI-XVII, VI-XVIII, VIII-III, XIV-I, XXI-II

2-Thienyl-MgI, VI-XVIII, VI-XIX, VIII-III, X-I, XI-I, XIII-I, XXII-I

3-Thienyl-MgBr, VIII-III, XIII-I

C₄H₄N

Pyrryl-MgBr, 75, 75-78, VI-XVII, VI-XVIII, VII-II, VIII-III, IX-II, X-I, XII-I, XIII-I, XVI-I

Pyrryl-MgI, VIII-III, IX-II, XIII-I, XX-II

C₄H₅

C₂H₅C≡CMgBr, XIII-I, XIV-I

C₄H₅O

C₂H₅OC≡CMgBr, VI-XVII, VI-XVIII

C₄H₆

(=CHCH₂MgBr)₂, VI-XVIII

C₄H₆Br

H₂C=CBrCH₂CH₂MgBr, 34, XVI-I

C₄H₇

H₂C=CHCH₂CH₂MgBr, 33-34, VI-XIX, XIII-I

Butenyl-MgCl, * VI-XVIII, XVII-II

Butenyl-MgBr, † 24, 47-48, 60, VI-XVII, VI-XVIII, VIII-III, XIII-I, XVI-I, 1148, XVII-II, XVII-III, XVII-IV

*From CH₃CH=CHCH₂Cl and/or CH₃(H₂C=CH)CHCl; concerning the constitution of the butenyl Grignard reagents, see pp. 60, 1145-1157.

†From CH₃CH=CHCH₂Br and/or CH₃(H₂C=CH)CHBr; concerning the constitution of the butenyl Grignard reagents, see pp. 60, 1145-1157.

C₄H₇ (cont.)

Dibutenyl-Mg, XIII-I, XVII-II

H₂C=C(CH₃)CH₂MgCl, 28, VI-XVII, VI-XVIII, VI-XIX, VIII-III, XVI-I

H₂C=C(CH₃)CH₂MgBr, XXIII-III

(CH₃)₂C=CHMgBr, 37, VI-XVII

C₄H₇O

3-Tetrahydrofuryl-MgBr, XVI-I

C₄H₇O₂

H₃C₂O₂CCH₂MgCl, VIII-III

H₃C₂O₂CCH₂MgBr, VI-XVIII, VI-XIX, IX-II

C₄H₈

(—CH₂CH₂MgBr)₂, 35, VI-XVIII, XIII-I, XXIII-III

(—CH₂CH₂MgI)₂, XVI-I

C₄H₉

n-C₄H₉MgCl, 12, 19, 32, 52, 53, V-I, VI-XVII, VI-XVIII, VI-XIX, VIII-III, IX-I, XI-I, XIII-I, XIV-I, XVII-IV, XIX-I, XIX-VI, XIX-X, XIX-XI, XIX-XII, XIX-XIII, XIX-XIV, XXI-II, XXII-I

n-C₄H₉MgBr, 10, 13, 17, 19, 25, 30, 32, 47, 49, 52, V-I, VI-XVII, VI-XVIII, VI-XIX, VII-II, 575, VIII-III, VIII-IV, IX-I, IX-II, X-I, XI-I, XII-I, XIII-I, XIII-II, XIV-I, XVI-I, XVII-IV, XVIII-I, XIX-I, XIX-II, XIX-VI, XIX-VIII, XIX-X, XIX-XII, XIX-XIII, XIX-XIV, XXI-I, XXI-II, XXI-V, XXI-VI, XXII-I, XXIII-II, XXIII-III

n-C₄H₉MgI, 19, 32, 52, V-I, VI-XVII, VI-XVIII, VIII-III, IX-I, X-I, XIX-X, XIX-XII, XIX-XIII, XIX-XIV, XXI-II (*n*-C₄H₉)₂Mg, 91, X-I, 967, XIV-I, XIX-X

i-C₄H₉MgCl, 11, 26, 32, 56, VI-XVII, VI-XVIII, VI-XIX, VIII-III, X-I, XI-I, XII-I, XIV-I, XVI-I, XIX-I, XXII-I, XXIII-II

i-C₄H₉MgBr, 19, 32, 47, 49, V-I, VI-IX, VI-XVII, VI-XVIII, VI-XIX, VIII-III, 725, 726, 727, IX-II, X-I, XII-I, XIII-I, XIII-II, XIV-I, XVI-I, XVII-IV, XIX-I, XIX-VI, XX-II, XXI-IV, XXII-I, XXIII-III

i-C₄H₉MgI, 32, VI-XVII, VI-XVIII, IX-II, XIII-II, XVI-I

s-C₄H₉MgCl, 26, 30, 53, VI-XVII, XIII-I, XIV-I, XIX-I, XIX-VI, XIX-XII, XIX-XIII, XIX-XIV

s-C₄H₉MgBr, 19, 47, 49, V-I, VI-I, VI-XVII, VI-XVIII, VI-XIX, VIII-III, VIII-IV, X-I, XI-I, XIII-I, XIII-II, XIV-I, XVI-I, XVII-IV, XIX-I, XIX-XII

s-C₄H₉MgI, XIX-XII

C₄H₉ (*cont.*)

t-C₄H₉MgCl, 10, 17, 19, 26-27, 47, 49, V-I, VI-XVII, VI-XVIII, VI-XIX, 560, VIII-III, VIII-IV, 725, 726, 731, IX-II, X-I, XI-I, XII-I, XIII-I, XIII-II, XIV-I, XVI-I, XIX-I, XIX-VI, XIX-XII, XIX-XIII, XIX-XIV, XX-I, XX-II

t-C₄H₉MgBr, 19, V-I, VI-XVII, IX-I, X-I, XIII-II, XIV-I, XVI-I, XVII-IV, XIX-XIII, XIX-XIV

t-C₄H₉MgI, VI-XVIII, X-I, XVI-I, XIX-XIII, XIX-XIV, XXI-I

t-C₄H₉MgX, VI-IX

(*t*-C₄H₉)₂Mg, XIV-I

C₄H₉O

CH₃O(CH₂)₃MgCl, VI-XVII, VIII-III, X-I

CH₃O(CH₂)₃MgBr, 36, X-I

CH₃O(CH₂)₃MgI, 36, X-I

C₄H₁₁Si

(CH₃)₃SiCH₂MgCl, VI-XVII, IX-II, XIII-I, XIV-I, XXII-I

C₅H₉N

2,6-Pyridylidene-(MgBr)₂, VI-XVII

C₅H₄N

2-Pyridyl-MgBr, 41, VI-XVII, VI-XVIII, VIII-III, XXIII-III

3-Pyridyl-MgBr, 41, XXIII-III

C₅H₄O

BrMgOCH₂CH=CHC≡CMgBr, VI-XVII, XIII-I

C₅H₈

(CH)₅MgBr,* 71, 120, VI-XVIII, X-I

H₂C=C(CH₃)C≡CMgBr, VI-XVII, VI-XVIII, XIV-I

C₅H₅O

3-Furfuryl-MgCl, VI-XVII, XIII-I, XVII-I

C₅H₃S

2-Thenyl-MgCl, 24, VI-XVII, IX-II, XI-I, XIII-I, XVII-I

2-Thenyl-MgBr, XIV-I

3-Thenyl-MgBr, XIII-I, XVII-I

5-Methyl-2-thienyl-MgBr, XIII-I

C₅H₅N

N-Methylpyrrol-MgBr, 80

2-Methylpyrrol-MgBr, IX-II

C₅H₆O

BrMgO(CH₃)₂CC≡CMgBr, VI-XIX

C₅H₇

n-C₅H₇C≡CMgBr, VI-XVII, VIII-III, X-I, XIV-I, XVI-I, XXI-II, XXIII-I

n-C₅H₇C≡CMgI, XVI-I

i-C₅H₇C≡CMgBr, VI-XVIII, VIII-III, XXIII-I

C₅H₉

H₂C=CH(CH₂)₃MgBr, 33-34, VI-XIX

CH₃CH=CHCH₂CH₂MgBr, 33-34, XIII-I

(CH₂)₄CHMgCl, VI-XVII, VIII-III, XIII-I, XIV-I, XVI-I, XVII-IV

(CH₂)₄CHMgBr, VI-XVII, VI-XVIII, VIII-III, X-I, XIII-I, XVI-I, XVII-IV

(CH₃)₂C=C(CH₃)MgBr, 37

C₅H₉O₂

H₅C₂O₂CCH₂CH₂MgCl, VI-XIX

H₅C₂O₂CCH₂CH₂MgBr, VI-XIX

C₅H₁₀

H₂C(CH₂CH₂MgCl)₂, X-I

H₂C(CH₂CH₂MgBr)₂, 35, VI-XVIII, VIII-III, XIII-I, XVI-I, XIX-VI, XXII-I, XXIII-III

H₂C(CH₂CH₂MgI)₂, XVI-I

C₅H₁₁

n-C₅H₁₁MgCl, XIV-I, XVI-I, XIX-I, XIX-XI, XIX-XII, XXII-I

n-C₅H₁₁MgBr, 19, 25, 30, VI-I, VI-XVII, VI-XVIII, VIII-III, IX-I, IX-II, X-I, XII-I, XIV-I, XIX-I, XXI-V, XXII-I, XXIII-II, XXIII-III

n-C₅H₁₁MgI, VI-XVII

i-C₅H₁₁MgCl, 32, 53, 109, XI-I, XII-I, XVI-I, XIX-I, XIX-VI, XXII-I, XXIII-I, XXIII-II

i-C₅H₁₁MgBr, 11, 19, 32, 56, V-I, VI-XVII, VI-XVIII, VI-XIX, VII-II, VIII-III, IX-I, IX-II, X-I, XI-I, XII-I, XIII-II, XIV-I, XVI-I, XIX-I, XIX-VI, XXI-IV, XXI-V, XXII-I, XXIII-III

i-C₅H₁₁MgI, 32, 54, VI-XVIII, VIII-III, XIII-II, XVI-I, XIX-II, XIX-VI

i-C₅H₁₁MgX, XIII-I

(*i*-C₅H₁₁)₂Mg, VI-XVIII

D(+)-*s*-C₄H₉CH₂MgCl,† 155, VI-XVII, VI-XVIII

D(+)-*s*-C₄H₉CH₂MgBr,† XI-I

s-C₄H₉CH₂MgBr, VI-XVII, VI-XVIII, IX-I, XIV-I, XVI-I, XIX-I, XXIII-III

t-C₄H₉CH₂MgCl, 30, VI-IX, VI-XVIII, IX-II, XXIII-I

t-C₄H₉CH₂MgBr, XIV-I

CH₃(*n*-C₃H₇)CHMgCl, XIX-I

CH₃(*n*-C₃H₇)CHMgBr, VI-XVII, IX-I, IX-II, XIV-I, XVI-I, XIX-I

CH₃(*i*-C₃H₇)CHMgBr, XIV-I

(C₂H₅)₂CHMgCl, XIV-I, XIX-I

(C₂H₅)₂CHMgBr, XVI-I, XIX-I

(C₂H₅)₂CHMgI, XVI-I

"*s*-C₅H₁₁MgBr," 19

t-C₅H₁₁MgCl, 26-27, VI-XVII, VIII-III, 726, IX-II, XII-I, XIII-I, XIV-I, XIX-I, XIX-VIII, XX-I

*5-Cyclopentadienylmagnesium bromide.

†From D(+)-*s*-C₄H₉CH₂Cl.

‡From D(+)-*s*-C₄H₉CH₂Br.

C₅H₁₁ (cont.)

t-C₅H₁₁MgBr, 19, VI-XVII, VI-XVIII, XIV-I

C₅H₁₁O

CH₃O(CH₂)₄MgCl, X-I

C₂H₅O(CH₂)₃MgBr, VI-XVIII, VI-XIX, X-I

CH₃OCH₂CH(CH₃)CH₂MgCl, VI-XVII, XIV-I

C₅H₁₂N

(CH₃)₂N(CH₂)₃MgCl, VI-I, VI-XVII

C₆H₅S₂

Thiophthenyl-MgBr, * 75, XIII-I

Thiophthenyl-MgI, * X-I

C₆H₄

(—CH₂C≡CMgBr)₂, XVI-I

C₆H₄-1,4-(MgBr)₂, 43, XIII-I, XVI-I

C₆H₄Br

3-BrC₆H₄MgBr, XIII-I

4-BrC₆H₄MgBr, 30, 39, VI-XVII, VI-XVIII, VIII-III, XI-I, XIII-I, XIII-II, XVI-I, XVII-IV, XIX-VI, XXI-I, XXI-II, XXI-IV, XXII-I, XXIII-I, XXIII-II

4-BrC₆H₄MgI, VII-II

C₆H₄Cl

2-ClC₆H₄MgBr, X-I, XI-I

2-ClC₆H₄MgI, VI-XVII

2-ClC₆H₄MgX, VI-XIX, VII-II

3-ClC₆H₄MgBr, VI-XVII

3-ClC₆H₄MgI, VI-XVIII, XII-I

4-ClC₆H₄MgBr, VI-XVIII, VII-II, VIII-III, X-I, XI-I, XII-I, XIII-I, XVI-I, XIX-XV, XXI-IV, XXII-I, XXIII-II, XXIII-III

4-ClC₆H₄MgI, VI-XVII, VI-XVIII, VI-XIX, VII-II, VIII-III

C₆H₄F

3-FC₆H₄MgBr, VI-XVII

4-FC₆H₄MgBr, VI-XVII, VII-II

C₆H₄O

2-BrMgOC₆H₄MgBr, † 90, VI-XVIII

C₆H₅

C₆H₅MgCl, 41, 54-55, 56, IX-II, XIII-I, XIV-I, XVI-I, XIX-XII, XIX-XIII, XXII-I

C₆H₅MgBr, 11, 13, 17, 19, 28, 47, 49, 53, 54, 56, 92, 96, 104, 105, 109, 120-121, V-I, VI-I, VI-V, VI-VI, VI-XVII, VI-XVIII, VI-XIX, 531, VII-II, VIII-III, VIII-IV, IX-I, IX-II, X-I, XI-I, XII-I, XIII-I, XIII-II, XIV-I, 1051-1052, 1055, XVI-I, XVII-IV, XIX-I, XIX-II, XIX-III, XIX-VI, XIX-VII, XIX-VIII, XIX-XV, XX-II, XXI-I, XXI-II, XXI-III,

C₆H₅ (cont.)

XXI-IV, XXI-V, XXI-VI, XXI-VII, XXII-I, XXIII-I, XXIII-II, XXIII-III

C₆H₅MgI, 54, 105, V-I, VI-XVII, VI-XVIII, VII-II, IX-II, XII-I, XIII-I, XIV-I, XVI-I, XIX-IL, XIX-IV, XIX-VI, XX-II, XXI-I, XXIII-I

(C₆H₅)₂Mg, 2, 3, 105, 106, VIII-IV, 1015, 1257

C₆D₅

C₆D₅MgBr, VI-XVIII

C₆H₅O

4-BrMgOC₆H₄MgBr, 54, XIII-I

C₆H₆Br

HBrC≡CH(CH₂)₂C≡CMgBr, VI-XVII

H₂C=CBr(CH₂)₂C≡CMgBr, XIII-I

C₆H₆IO

2,5-Dimethyl-4-iodo-3-furyl-MgI, XIII-I

C₆H₆N

2-Pyridylmethyl-MgBr, IX-II, XIV-I, XVII-I,

2-Pyridylmethyl-MgI, IX-II, XIV-I, XVII-I

2-H₂NC₆H₄MgBr, 54

3-H₂NC₆H₄MgBr, 54

C₆H₆O

CH₃CH=CHCH(OMgBr)C≡CMgBr, VI-XVII, VI-XVIII

BrMgOCH₂CH=C(CH₃)C≡CMgBr, VI-XVII

C₆H₇

CH₃CH=C(CH₃)C≡CMgBr, VI-XVII, VI-XVIII

CH₃CH=C(CH₃)C≡CMgX, XXII-I

C₆H₇S

5-Methyl-2-thenyl-MgBr, XVII-I

5-Methyl-3-thenyl-MgBr, XIII-I

2,5-Dimethyl-3-thienyl-MgI, 41, XIII-I

C₆H₈N

2-Ethylpyrryl-MgBr, IX-I

2,3-Dimethylpyrryl-MgBr, IX-II

2,3-Dimethylpyrryl-MgX, VIII-III

2,4-Dimethylpyrryl-MgBr, 78, VIII-III, IX-II

2,5-Dimethylpyrryl-MgBr, 79, IX-II

2,5-Dimethylpyrryl-MgX, VIII-III

3,5-Dimethylpyrryl-MgI, IX-II

C₆H₈O

BrMgO(CH₃)(C₂H₅)CC≡CMgBr, VI-XVII, VI-XIX, XIII-I

C₆H₈O₂

[C₂H₅CH=CHCH(CO₂MgCl)]⁻MgCl⁺, XIII-I

C₆H₉

n-C₃H₇C≡CCH₂MgBr, XIII-I

*Orientation uncertain.

†From 2-ClHgC₆H₄OH + C₂H₅MgBr.

C₆H₉ (*cont.*)

n-C₄H₉C≡CMgCl, 67, VIII-III, IX-II, XI-I

n-C₄H₉C≡CMgBr, 67, V-I, VI-XVII, VI-XVIII, VI-XIX, IX-II, XI-I, XIV-I, 1053, XVI-I, XIX-II, XX-II, XXI-I

n-C₄H₉C≡CMgI, 67, IX-II, XI-I

t-C₄H₉C≡CMgBr, VI-XVIII, VIII-III

C₆H₉O

CH₃(C₂H₅O)CHC≡CMgBr, XIII-I

C₆H₁₁

CH₃CH=CH(CH₂)₃MgBr, XIII-I

C₂H₅CH=CH(CH₂)₂MgBr, XIX-I

(CH₃)₂C=CH(CH₂)₂MgBr, VI-XVII

(CH₂)₄CHCH₂MgBr, VI-XVII

3-Methylcyclopentyl-MgI, XIII-I

(CH₂)₅CHMgCl, 6, VI-I, VI-XVII, VI-XVIII, VIII-III, X-I, XII-I, XIII-I, XIV-I, XVI-I, XIX-I, XX-I, XX-II, XXI-V, XXII-I

(CH₂)₅CHMgBr, 6, 30, 40, 44, 47, V-I, VI-XVII, VI-XVIII, VI-XIX, VIII-III, IX-II, X-I, XI-I, XIII-I, XIV-I, XVI-I, XIX-I, XIX-VI, XIX-VIII, XX-I, XXI-I, XXI-II, XXI-VI, XXII-I, XXIII-II, XXIII-III

(CH₂)₅CHMgI, XIII-I

(CH₂)₄C(CH₃)MgCl, XIII-I

C₆H₁₁O₂

H₅C₂O₂CCH(CH₃)CH₂MgBr, VI-XIX

H₅C₂O₂CCH(CH₃)CH₂MgI, VI-XIX

i-C₄H₉O₂CCH₂MgCl, VIII-III

C₆H₁₂

[—(CH₂)₃MgBr]₂, XIII-I

C₆H₁₃

n-C₆H₁₃MgCl, 32, VI-XVIII, VIII-III, XXII-I

n-C₆H₁₃MgBr, 11, 19, 25, 32, 56, V-I, VI-XVII, VI-XVIII, VI-XIX, VIII-III, IX-II, XII-I, XIV-I, XVI-I, XIX-I, XXI-II, XXII-I, XXIII-II, XXIII-III

n-C₆H₁₃MgI, 32, VI-XVII

i-C₆H₁₃MgBr, VI-XVII, IX-II, X-I, XIV-I, XXIII-III

(+)-*s*-C₄H₉(CH₂)₂MgCl, VI-XVIII

t-C₄H₉(CH₂)₂MgCl, VI-XVII, XIII-I, XIV-I

n-C₃H₇CH(CH₃)CH₂MgBr, X-I

CH₃(*n*-C₄H₉)CHMgCl, XIX-I

CH₃(*n*-C₄H₉)CHMgBr, 30, XIV-I

CH₃(*i*-C₄H₉)CHMgCl, XX-II

CH₃(*i*-C₄H₉)CHMgBr, VI-XVII

n-C₃H₇(CH₃)₂CMgCl, XX-II

n-C₃H₇(CH₃)₂CMgBr, XIV-I

CH₃(C₂H₅)₂CMgCl, 26-27, IX-II, XIII-I

C₆H₁₃O

CH₃O(C₂H₅)CH(CH₂)₂MgCl, VI-XVIII

C₆H₁₃O₂

(C₂H₅O)₂CHCH₂MgBr, VI-XVIII

C₆H₁₅Si

(CH₃)₃Si(CH₂)₃MgBr, XIV-I

C₆H₁₇Si₂O

(CH₃)₃SiOSi(CH₃)₂CH₂MgCl, 30, XIII-I, XXII-I

C₇H₅BrF₃

2-Br-4-F₃CC₆H₃MgBr, VI-XVII

C₇H₅F₄

3-F₃C-4-FC₆H₃MgBr, VI-XVII

C₇H₄F₃

2-F₃CC₆H₄MgBr, 30, XIII-I

2-F₃CC₆H₄MgI, XIII-I

3-F₃CC₆H₄MgBr, VI-XVII, XIV-I, XXI-I

4-F₃CC₆H₄MgBr, 30, XIII-I

C₇H₅Cl₂

2,6-Cl₂C₆H₃CH₂MgCl, IX-II, XI-I, XIII-I, XVII-I

C₇H₆Br

2-BrC₆H₄CH₂MgBr, XIV-I

4-BrC₆H₄CH₂MgBr, 39, XVI-I

C₇H₆Cl

2-ClC₆H₄CH₂MgCl, IX-II, XI-I, XII-I, XIII-I, XVII-I

3-ClC₆H₄CH₂MgCl, XII-I

4-ClC₆H₄CH₂MgCl, VI-XVIII, XII-I, XVI-I, XIX-I

C₇H₆FO

3-F-4-CH₃OC₆H₃MgBr, XIV-I

C₇H₆O₂S

C₆H₅SO₂CH(MgI)₂,* 74

C₇H₇

C₆H₅CH₂MgCl, 13, 17, 19, 30, 53, 109, V-I, VI-XVII, VI-XVIII, VI-XIX, VII-II, 575, 577, 578, VIII-III, VIII-IV, IX-I, 731, IX-II, X-I, XI-I, XII-I, XIII-I, XIII-II, XIV-I, 1052, XVI-I, 1133, XVII-I, XVII-IV, XIX-I, XIX-II, XIX-III, XIX-V, XIX-VI, XIX-XI, XIX-XII, XIX-XIII, XIX-XIV, XX-I, XX-II, XXI-I, XXI-II, XXI-IV, XXI-V, XXI-VI, XXI-VII, XXII-I, XXIII-II

C₆H₅CH₂MgBr, 24, VI-VI, VI-XVII, VI-XVIII, VI-XIX, VIII-III, IX-II, X-I, XIII-I, XVI-I, XVII-I, XIX-I, XIX-VIII, XXI-II

C₆H₅CH₂MgI, VI-VI, XVI-I, XVII-I

2-CH₃C₆H₄MgCl, VI-XIX

2-CH₃C₆H₄MgBr, 19, V-I, VI-XVII, VI-XVIII, VI-XIX, VII-II, VIII-III, VIII-IV, IX-II, X-I, XI-I, XII-I, XIII-I, XIV-I, XVI-I, XVII-IV, XIX-II, XX-II, XXI-II, XXI-IV, XXII-I, XXIII-I, XXIII-II

*This compound is undoubtedly analogous to the enolates that behave as true Grignard reagents.

C₇H₇ (cont.)

- 2-CH₃C₆H₄MgI, VI-XIX, XVI-I
 3-CH₃C₆H₄MgCl, XIII-II
 3-CH₃C₆H₄MgBr, 19, VI-XVII, VI-XVIII, VI-XIX, VII-II, VIII-III, VIII-IV, X-I, XII-I, XIII-II, XIV-I, XVI-I, XX-II, XXII-I, XXIII-I, XXIII-II
 3-CH₃C₆H₄MgI, VI-XIX
 4-CH₃C₆H₄MgCl, XIII-II, XIX-V
 4-CH₃C₆H₄MgBr, 13, 19, 30, V-I, VI-XVII, VI-XVIII, VI-XIX, VII-II, VIII-III, VIII-IV, IX-II, X-I, XI-I, XII-I, XIII-II, XIV-I, XVI-I, XVII-IV, XIX-I, XIX-III, XIX-IV, XIX-VII, XX-II, XXI-I, XXI-II, XXI-III, XXI-IV, XXI-VI, XXII-I, XXIII-I, XXIII-II
 4-CH₃C₆H₄MgI, 54, VI-XVII, VI-XIX, VII-II, VIII-III, XII-I

C₇H₇O

- 2-CH₃OC₆H₄MgBr, 74, VI-XVIII, VII-II, VIII-III, IX-II, X-I, XI-I, XIV-I, XXIII-II
 2-CH₃OC₆H₄MgI, VI-XVIII, VI-XIX, VIII-III
 2-CH₃OC₆H₄MgX, IX-II
 3-CH₃OC₆H₄MgBr, VI-XVII, VI-XIX, VII-II, XIV-I, XXIII-II
 3-CH₃OC₆H₄MgI, VI-XVIII, VI-XIX, XIV-I
 4-CH₃OC₆H₄MgBr, V-I, VI-XVII, VI-XVIII, VI-XIX, VII-II, VIII-III, VIII-IV, IX-II, X-I, XI-I, XII-I, XIII-I, XIV-I, XVI-I, XVII-IV, XIX-IV, XX-II, XXI-I, XXI-II, XXIII-II, XXIII-III
 4-CH₃OC₆H₄MgI, VI-XVIII, VI-XIX, VII-II, VIII-III, XI-I

C₇H₇O₂S

- C₆H₅SO₂CH₂MgBr, VI-XVII

C₇H₇S

- 4-CH₃SC₆H₄MgBr, VIII-III

C₇H₉O

- CH₃O(CH₂)CHCH=CHC≡CMgBr, VI-XVII
 CH₃OCH₂CH=C(CH₃)C≡CMgBr, XIV-I

C₇H₁₀N

- 2-Methyl-4-ethylpyrrol-MgBr, IX-II
 Xanthopyrrol-MgBr, * IX-II
 2,3,4-Trimethylpyrrol-MgBr, IX-II
 2,3,5-Trimethylpyrrol-MgBr, 79

C₇H₁₁

- CH₃CH=C(CH₃)CH=CHCH₂MgBr, VI-XVIII
 1-Cyclohexenylmethyl-MgCl, VI-XVII

C₇H₁₁ (cont.)

- n*-C₄H₉C≡CCH₂MgBr, 24, XIII-I
n-C₅H₁₁C≡CMgCl, 67, IX-II, XI-I
n-C₅H₁₁C≡CMgBr, 66-67, VI-XVII, VI-XVIII, VIII-III, IX-II, X-I, XII-I, XIV-I, XVI-I, XXIII-I
n-C₅H₁₁C≡CMgI, 67, IX-II

C₇H₁₁O₂

- (C₂H₅O)₂CHC≡CMgBr, VI-XVII, VIII-III, XXIII-I

C₇H₁₃

- n*-C₃H₇CH=CH(CH₂)₂MgBr, XIX-I
 (CH₂)₅CHCH₂MgCl, XIV-I
 (CH₂)₅CHCH₂MgBr, VI-XVII
 (CH₂)₅CHCH₂MgI, VI-XVII
 3-Ethylcyclopentyl-MgBr, XVI-I
 (CH₂)₆CHMgBr, XIII-I
 (CH₂)₆CHMgI, VI-XVII
 2-Methylcyclohexyl-MgCl, XIII-I
 2-Methylcyclohexyl-MgBr, VI-XVII, VIII-III, X-I
 3-Methylcyclohexyl-MgCl, X-I, XIII-I
 3-Methylcyclohexyl-MgBr, X-I
 3-Methylcyclohexyl-MgI, XIII-I
 4-Methylcyclohexyl-MgCl, XIII-I
 4-Methylcyclohexyl-MgBr, X-I
 (CH₂)₅C(CH₃)MgCl, XIII-I

C₇H₁₃O

- H₂C=CH[CH₂O(CH₂)₃]CHMgCl, XIII-I

C₇H₁₃O₂

- H₃C₂O₂CCH(C₂H₅)CH₂MgBr, VI-XIX

C₇H₁₄

- H₂C[(CH₂)₃MgBr]₂, XIII-I, XVI-I

C₇H₁₄O

- H₂C=CH[CH₂O(CH₂)₃]CHMgCl, XIII-I

C₇H₁₅

- n*-C₇H₁₅MgCl, 32, 52, XVII-IV
n-C₇H₁₅MgBr, 19, 32, 47, 49, VI-XVII, VI-XIX, VIII-III, IX-II, X-I, XII-I, XIV-I, XVI-I, XIX-I, XXI-II, XXII-I
n-C₇H₁₅MgI, 32, VI-XVII
 CH₃(*n*-C₃H₇)CH(CH₂)₂MgBr, VI-XVII, XIV-I
 CH₃(*i*-C₃H₇)CH(CH₂)₂MgCl, XX-II
 CH₃(*i*-C₄H₉)CHCH₂MgBr, VIII-III
 CH₃(*n*-C₅H₁₁)CHMgBr, VI-XVII
 CH₃(*i*-C₅H₁₁)CHMgCl, XX-II
 CH₃(*t*-C₄H₉)CHMgCl, XX-II
 (*n*-C₃H₇)₂CHMgBr, VI-XVIII, XVI-I
 (*i*-C₃H₇)₂CHMgBr, VIII-III
n-C₄H₉(CH₂)₂CMgCl, 26-27, IX-II, XIII-I, XX-II
i-C₄H₉(CH₂)₂CMgCl, XX-II
t-C₄H₉(CH₂)₂CMgCl, XX-II

*From 2-ethyl-4-methylpyrrole.

C₇H₁₅ (*cont.*)

CH₃(C₂H₅)(*n*-C₃H₇)CMgCl, 26-27, VI-XVII

CH₃(C₂H₅)(*i*-C₃H₇)CMgCl, XX-II

(C₂H₅)₃CMgCl, 26-27, VI-XVII, XIII-I

C₇H₁₅O

C₂H₅[CH₃O(CH₂)₃]CHMgCl, XIII-I

C₇H₁₆N

(C₂H₅)₂N(CH₂)₃MgCl, VI-XVII, VI-XVIII, X-I

C₈H₄Br

4-BrC₆H₄C≡CMgBr, XXI-II

C₈H₅

C₆H₅C≡CMgCl, 67, XI-I

C₆H₅C≡CMgBr, 66-67, 96, V-I, VI-XVII, VI-XVIII, VII-II, VIII-III, IX-II, X-I, XI-I, XIII-I, XIV-I, 1053, XVI-I, XIX-I, XX-II, XXI-I, XXI-II, XXI-VI, XXII-I, XXIII-I

C₆H₅C≡CMgI, 67, VIII-III, 1054, XVI-I

C₈H₅BrO₂

[2-BrC₆H₄CH(CO₂MgCl)]⁻MgX,⁺ XIII-I

[3-BrC₆H₄CH(CO₂MgCl)]⁻MgX,⁺ XIII-I

C₈H₅ClO₂

[2-ClC₆H₄CH(CO₂MgCl)]⁻MgX,⁺ VI-XVII, VI-XVIII, XIII-I

[3-ClC₆H₄CH(CO₂MgCl)]⁻MgX,⁺ XIII-I

[4-ClC₆H₄CH(CO₂MgCl)]⁻MgX,⁺ XIII-I

C₈H₅O

C₆H₅OC≡CMgBr, VI-XVII, VI-XVIII, IX-II, XXI-II, XXIII-I

C₈H₅S

3-Thianaphthenyl-MgBr, XI-I

C₈H₆N

Indolyl-MgBr, VI-XVII, VIII-III, IX-II, XXIII-III

Indolyl-MgI, 80-81, VIII-III, X-I, XIII-I, XVI-I

Indolyl-MgX, XIV-I

C₈H₆NS

2-Benzothiazolylmethyl-MgBr, 74-75, VI-XVIII, XIII-I

C₈H₆O₂

[C₆H₅CH(CO₂MgCl)]⁻MgX,⁺ VI-XVIII, XIII-I

C₆H₅CH(CO₂MgX)MgX,^{*} 72-73

[C₆H₅CH(CO₂Na)]⁻MgCl,⁺ VI-XVII, VI-XVIII, VIII-III, IX-II, XI-I, XXIII-I

C₈H₆O₂ (*cont.*)

[C₆H₅CH(CO₂Na)]⁻MgX,⁺ VI-XIX, XX-II

C₈H₇

C₆H₅CH=CHMgBr, 11, 12, 29, 37, 49, V-I, VI-XVIII, VI-XIX, XIII-I, XIX-I, XXI-VI

C₈H₇O

[C₆H₅COCH₂]⁻MgBr,⁺ 90

C₈H₈Br

2,3-(CH₃)₂-4-BrC₆H₂MgBr, VIII-III

C₈H₈O₂S

4-CH₃C₆H₄SO₂CH(MgBr)₂, IX-II

C₈H₉

C₆H₅(CH₂)₂MgCl, VI-XIX, XIV-I, XIX-I, XIX-XII, XIX-XIII, XIX-XIV

C₆H₅(CH₂)₂MgBr, 47, VI-XVII, VI-XVIII, VI-XIX, IX-I, XII-I, XIII-I, XIV-I, XVI-I, XVII-IV, XX-II

2-CH₃C₆H₄CH₂MgBr, VI-XVII, VI-XVIII, XIII-I, XIV-I, XVI-I, XVII-I, XXI-V

3-CH₃C₆H₄CH₂MgBr, VI-XVII, VI-XVIII, XIII-I, XIV-I, XVI-I, XVII-I, XXI-V

4-CH₃C₆H₄CH₂MgCl, XVI-I, XXI-II

4-CH₃C₆H₄CH₂MgBr, VI-XVII, XIII-I, XIV-I, XVI-I, XVII-I, XXI-V

4-CH₃C₆H₄CH₂MgX, VIII-III

CH₃(C₆H₅)CHMgCl, XVII-I

/CH₃(C₆H₅)CHMgBr, VI-XVII, VI-XIX, X-I

1-Cyclohexenylethynyl-MgBr, VI-XVII, VI-XVIII, XI-I

2-C₂H₅C₆H₄MgBr, VI-XVIII, XXI-I

4-C₂H₅C₆H₄MgBr, VI-XVIII, XXI-I

2,3-(CH₃)₂C₆H₃MgBr, VI-XVII, VI-XIX, IX-II, XI-I, XIV-I

2,4-(CH₃)₂C₆H₃MgBr, 105, VIII-III, X-I, XI-I, XVI-I, XXI-I, XXI-II

2,4-(CH₃)₂C₆H₃MgI, 105, XVI-I, XXI-I, XXII-I

[2,4-(CH₃)₂C₆H₃]₂Mg, 105

2,5-(CH₃)₂C₆H₃MgBr, V-I, VI-XVII, VIII-III, X-I, XVI-I, XXI-II, XXIII-II

2,6-(CH₃)₂C₆H₃MgI, XXI-I

2,6-(CH₃)₂C₆H₃MgX, IX-II

3,4-(CH₃)₂C₆H₃MgBr, VI-XIX, VII-II

3,5-(CH₃)₂C₆H₃MgBr, VI-XVII, XI-I

C₈H₉NO₂

(C₈H₉NO₂MgBr)MgBr,[†] IX-II

C₈H₉O

4-CH₃OC₆H₄CH₂MgCl, 30

4-CH₃OC₆H₄CH₂MgBr, XIII-I

CH₃OCH₂C≡CCH₂CH₂C≡CMgI, XIII-I

2-CH₃OCH₂C₆H₄MgBr, 41, XIV-I

*In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1951), this "Grignard reagent" should be formulated as an enolate.

†From "opsopyrrolecarboxylic acid."

C₆H₅O (cont.)

2-C₂H₅OC₆H₄MgBr, 74, VII-II, VIII-III, XIV-I

3-C₂H₅OC₆H₄MgBr, VII-II

4-C₂H₅OC₆H₄MgBr, VI-XVIII, VI-XIX, VII-II, VIII-III, XIII-I, XVI-I, XIX-III

2-CH₃O-4-CH₃C₆H₃MgBr, XIV-I

2-CH₃O-5-CH₃C₆H₃MgBr, VI-XIX, XIV-I

3-CH₃-5-CH₃OC₆H₃MgBr, XVI-I

C₆H₅O₂

2,4-(CH₃O)₂C₆H₃MgI, VI-XVIII, VIII-III, VIII-IV

2,5-(CH₃O)₂C₆H₃MgBr, X-I, XII-I

2,6-(CH₃O)₂C₆H₃MgI, VIII-III

3,4-(CH₃O)₂C₆H₃MgBr, 39, 41, VIII-IV

3,4-(CH₃O)₂C₆H₃MgI, XIII-I

C₆H₅O₂S

CH₃(C₆H₃SO₂)CHMgBr, XIII-I

C₆H₁₀N

2-(CH₃)₂NC₆H₄MgBr, XIII-I

2-(CH₃)₂NC₆H₄MgI, VI-XVIII, VIII-III

4-(CH₃)₂NC₆H₄MgBr, 10-11, 41, VI-XVIII, XII-I, XXIII-III

4-(CH₃)₂NC₆H₄MgI, 10, VI-XVIII

C₆H₁₀NO₂

2-Methyl-3-carbethoxypyrryl-MgBr, IX-II

C₆H₁₀O

(CH₂)₅C(OMgBr)C≡CMgBr, VI-XVIII, VI-XIX

C₆H₁₁

(CH₂)₅CHC≡CMgBr, VI-XVII, X-I, XXIII-I

C₆H₁₁O

CH₃[α-furyl-(CH₂)₂]CHMgBr, XIX-I

C₂H₅OCH₂CH=C(CH₃)C≡CMgBr, VI-XVII

C₆H₁₂N

2,4-Diethylpyrryl-MgBr, IX-II

2,5-Dimethyl-3-ethylpyrryl-MgBr, 79

Hemopyrryl-MgBr, * VIII-III

Cryptopyrryl-MgBr, † VIII-III, IX-II, XX-II

2,3,4,5-Tetramethylpyrryl-MgX, 79

C₆H₁₃

n-C₅H₁₁C≡CCH₂MgBr, XIII-I, XIV-I

CH₃(*n*-C₄H₉C≡C)CHMgBr, XIII-I

n-C₆H₁₃C≡CMgBr, 67, VI-XVII, VIII-III, XVI-I, XXI-I, XXIII-I

CH₃(C₂H₅)₂CC≡CMgBr, VI-XVIII, VIII-III

C₆H₁₃

(CH₂)₄CH(CH₂)₃MgBr, X-I

C₃H₁₅ (cont.)

(CH₂)₅CH(CH₂)₂MgBr, VI-XVII, XIV-I

n-C₄H₉CH=CH(CH₂)₂MgBr, XIX-I

Octenyl-MgBr, † XIII-I

(CH₃)₂C=CH(CH₂)₂CH(CH₃)MgBr, VI-XVII, XIV-I

(CH₂)₅CHCH(CH₃)MgCl, XIV-I

3,3-Dimethylcyclohexyl-MgBr, VI-XVII, XIX-I, XXI-V

3,5-Dimethylcyclohexyl-MgI, XIII-I

C₆H₁₅O

[*t*-C₄H₉COC(CH₃)₂]⁻MgBr, † XIII-I

4-(Tetrahydro-2-furyl)-2-butylyl-MgBr, XIII-I

C₆H₁₆N

(CH₂)₅N(CH₂)₃MgCl, VI-XVII, VI-XVIII

C₆H₁₇

n-C₆H₁₇MgCl, 32, VI-XVII, XII-I

n-C₆H₁₇MgBr, 11, 19, 32, 56, VI-XVII, VI-XVIII, VIII-III, IX-II, X-I, XIV-I, XVI-I, XX-II, XXI-V, XXII-I

n-C₆H₁₇MgI, 32, 52, VI-XVII

i-C₆H₁₇MgBr, IX-II

t-C₄H₉(CH₂)₄MgCl, VI-XVII

CH₃(*n*-C₅H₇)CH(CH₂)₃MgBr, VI-XVII

t-C₄H₉(CH₂)₂CCH₂MgCl, XIII-I, XX-II

CH₃(*n*-C₆H₁₃)CHMgCl, XX-I

CH₃(*n*-C₆H₁₃)CHMgBr, VI-XVII, IX-II, XIX-I

"*s*-C₆H₁₇MgI," 54, VI-XIX

n-C₅H₁₁(CH₃)₂CMgCl, 26-27, VI-XVII, XIII-I

t-C₄H₉CH₂(CH₃)₂CMgCl, XIII-I

C₆H₁₇MgCl, § 41

CH₃(C₂H₅)(*n*-C₄H₉)CMgCl, VI-XVII

C₆H₁₇O

n-C₅H₁₁O(CH₂)₃MgBr, 36

n-C₅H₁₁O(CH₂)₃MgI, 36, XVI-I

[(C₂H₅)₃CCOCH₂]⁻MgBr, † VI-XVII

C₉H₇

C₆H₅C≡CCH₂MgBr, XIII-I

C₆H₅CH₂C≡CMgBr, X-I, XXIII-I

4-CH₃C₆H₄C≡CMgBr, VI-XVIII, VIII-III, X-I

1-Indenyl-MgBr, 71, VI-XVII, VI-XVIII, X-I, XIII-I, XXIII-I

2-Indenyl-MgBr, XIII-I

3-Indenyl-MgBr, XIII-I

C₉H₇O

2-HO-5-CH₃C₆H₃C≡CMgBr, XXIII-I

p-Cresyl-C≡CMgBr, X-I

†From a mixture of CH₃(CH₂)₄CH=CHCH₂Br and H₂C=CH[CH₃(CH₂)₄]-CHBr.

§From "diisobutylene hydrochloride"; the acid obtained upon carbonation is *t*-C₄H₉CH₂(CH₃)₂CCO₂H.

*From 2,3-dimethyl-4-ethylpyrrole.

†From 2,4-dimethyl-3-ethylpyrrole.

C₉H₇S

- 2-Thianaphthenylmethyl-MgCl, 24, VI-XVII, VI-XVIII, IX-II, XIII-I, XVII-I
 3-Thianaphthenylmethyl-MgCl, 24, VI-XVII, VI-XVIII, IX-II, XIII-I, XIV-I, XVII-I
 3-Methyl-2-thianaphthenyl-MgBr, VI-XVIII

C₉H₉N

- 2-Methylindolyl-MgBr, VI-XVII, VI-XVIII, VII-II, IX-II, XIII-I, XXIII-III
 2-Methylindolyl-MgI, VIII-III, X-I, XVI-I
 2-Methylindolyl-MgX, 82, VI-XVII
 3-Methylindolyl-MgBr, 83-84, IX-II, XIII-I
 3-Methylindolyl-MgI, XVI-I

C₉H₉NO

- 6-Methoxyindolyl-MgI, X-I, XVI-I

C₉H₈O₂

- [2-CH₃C₆H₄CH(CO₂MgCl)]⁻MgX,⁺ XIII-I
 [3-CH₃C₆H₄CH(CO₂MgCl)]⁻MgX,⁺ XIII-I
 [4-CH₃C₆H₄CH(CO₂MgCl)]⁻MgX,⁺ XIII-I

C₉H₉

- Cinnamyl-MgCl,* 28, 60, VI-XVII, XIII-I, 1146-1148
 C₆H₅CH₂C(=CH₂)MgBr, XIII-I
 C₆H₅CH₂CH=CHMgBr, XIII-I
 CH₃(C₆H₅)C=CHMgBr, 37, XIII-I
 4-H₂C=CHCH₂C₆H₄MgBr, VIII-III, XIII-I
 4-CH₃CH=CHC₆H₄MgBr, VI-XVII, VIII-III, XIII-I, XX-II

C₉H₁₁

- C₆H₅(CH₂)₃MgCl, XIV-I, XXI-II
 C₆H₅(CH₂)₃MgBr, VI-XVII, VI-XVIII, X-I, XIII-I, XIV-I, XVI-I
 2-CH₃C₆H₄(CH₂)₂MgX, VIII-III
 CH₃(C₆H₅)CHCH₂MgCl, XIII-I
 CH₃(C₆H₅)CHCH₂MgBr, XIII-I
 4-C₂H₅C₆H₄CH₂MgX, VIII-III
 2,4-(CH₃)₂C₆H₃CH₂MgCl, VI-XVIII, XVI-I
 2,4-(CH₃)₂C₆H₃CH₂MgX, VIII-III
 2,5-(CH₃)₂C₆H₃CH₂MgCl, XVI-I
 2,5-(CH₃)₂C₆H₃CH₂MgX, VIII-III
 3,5-(CH₃)₂C₆H₃CH₂MgBr, VI-XVII, XVII-I
 CH₃(C₆H₅CH₂)CHMgBr, XIII-I

C₉H₁₁ (cont.)

- C₂H₅(C₆H₅)CHMgBr, X-I
 C₆H₅(CH₃)₂CMgCl, X-I
 C₆H₅(CH₃)₂CMgBr (?),† VIII-III
 4-*n*-C₃H₇C₆H₄MgBr, VI-XVIII
 4-*i*-C₃H₇C₆H₄MgCl, XX-II
 4-*i*-C₃H₇C₆H₄MgBr, VI-XVIII, VIII-III, XIV-I, XVI-I, XVII-IV, XX-II, XXI-II
 2,3,4-(CH₃)₃C₆H₂MgBr, 41
 2,3,6-(CH₃)₃C₆H₂MgBr, VIII-III
 2,4,5-(CH₃)₃C₆H₂MgBr, VIII-III, XXI-IV
 2,4,6-(CH₃)₃C₆H₂MgBr, 29, 52, 105, V-I, VI-XVII, VI-XVIII, VI-XIX, VIII-III, VIII-IV, IX-I, IX-II, X-I, XI-I, XII-I, XIII-I, XIV-I, XVI-I, XIX-VI, XXI-I, XXI-IV
 [2,4,6-(CH₃)₃C₆H₂]₂Mg, 105

C₉H₁₁NO₂

- (C₉H₁₁NO₂MgBr)MgBr,† IX-II

C₉H₁₁O

- C₆H₅O(CH₂)₃MgBr, X-I
 3-CH₃OC₆H₄(CH₂)₂MgCl, VI-XIX
 4-CH₃OC₆H₄(CH₂)₂MgCl, VI-XIX
 2-C₂H₅OCH₂C₆H₄MgBr, 41, VI-XVIII, VI-XIX, XIV-I
 4-*n*-C₃H₇OC₆H₄MgBr, VIII-III
 2,6-(CH₃)₂-4-CH₃OC₆H₂MgBr, IX-II, XIII-I

C₉H₁₂O₂

- 1-BrMgO-4-CH₃O-1-cyclohexylethynyl-MgBr, VI-XIX

C₉H₁₃Si

- C₆H₅(CH₃)₂SiCH₂MgCl, XIII-I

C₉H₁₄N

- 2,4-Dimethyl-3-*n*-propylpyrryl-MgBr, IX-II
 2-Methyl-3,4-diethylpyrryl-MgBr, IX-II
 2,3-Diethyl-4-methylpyrryl-MgBr, IX-II

C₉H₁₅

- n*-C₄H₉C≡C(CH₃)₂CMgBr, XIII-I

C₉H₁₇

- (CH₃)₂C=CH(CH₂)₂CH(CH₃)CH₂-MgBr, VI-XVII

C₉H₁₈O

- IMgO(CH₃)(*t*-C₄H₉)CC(CH₃)₂MgBr, XIII-I

†It is possible that the supposed Grignard reagent has not been prepared. From the attempted reaction with oxalic ester only bi-*α*-cumyl (the Wurtz product) was isolated. Brown, Mighton, and Senkus, *J. Org. Chem.*, 3, 62-75 (1938), report an unsuccessful attempt to prepare C₆H₅(CH₃)₂CMgCl.

†From "hemopyrrolecarboxylic acid."

*From C₆H₅CH=CHCH₂Cl; concerning the constitution of the cinnamyl Grignard reagents, see pp. 60, 1147-1148.

C₉H₁₉

- n -C₉H₁₉MgCl, XII-I
 n -C₉H₁₉MgBr, VI-XVII, XXI-V
 n -C₉H₁₉MgX, XVI-I
 i -C₉H₁₉MgBr, IX-I
 CH₃(C₆H₅)CH(CH₂)₅MgBr, IX-I
 CH₃(n -C₃H₇)CH(CH₂)₄MgBr, IX-I
 (n -C₄H₉)₂CHMgBr, VIII-III (?), X-I

C₉H₁₉O

- n -C₃H₁₁O(CH₂)₄MgI, X-I

C₉H₂₀N

- (C₂H₅)₂N(CH₂)₅MgCl, VI-XVII

C₁₀H₆

- C₁₀H₆-1,2-(MgBr)₂, XIII-I
 C₁₀H₆-1,4-(MgBr)₂, XIII-I
 C₁₀H₆-1,5-(MgBr)₂, XIII-I

C₁₀H₆Br

- 4-BrC₁₀H₆-1-MgBr, XIII-I, XX-II
 5-BrC₁₀H₆-2-MgBr, X-I, XIII-I, XX-II

C₁₀H₆Cl

- 4-ClC₁₀H₆-1-MgBr, XX-II
 4-ClC₁₀H₆-1-MgI, VI-XVII, XIII-I
 6-ClC₁₀H₆-2-MgBr, X-I

C₁₀H₇

- 1-C₁₀H₇MgCl, 41, XIII-I
 1-C₁₀H₇MgBr, 19, 30, 47, 49, V-I, VI-V, VI-XVII, VI-XVIII, VI-XIX, VII-II, 577, VIII-III, VIII-IV, IX-I, IX-II, XI-I, XII-I, XIII-I, XIV-I, 1055, XIX-I, XIX-II, XIX-III, XIX-V, XIX-VI, XIX-VII, XX-II, XXI-II, XXI-III, XXI-IV, XXI-VI, XXII-I, XXIII-II
 2-C₁₀H₇MgBr, 19, VI-XIX, VIII-IV, X-I, XI-I, XIII-I, XIV-I, XVI-I, XXI-IV
 2-C₁₀H₇MgI, VIII-III, XXII-I

C₁₀H₆N

- 2-Phenylpyrryl-MgBr, IX-II

C₁₀H₅O₂

- [C₆H₅CH=CHCH(CO₂MgX)]⁻MgX⁺, XIII-I

C₁₀H₉

- C₆H₅CH₂CH₂C≡CMgBr, X-I, XXIII-I
 2,4-(CH₃)₂C₆H₃C≡CMgBr, VIII-III, X-I, XXIII-I
 m -Xylyl—C≡CMgBr, X-I
 3,4-Dihydro-2-naphthyl-MgBr, X-I

C₁₀H₉S

- 3-Methyl-2-thianaphthenyl-MgBr, XIII-I

C₁₀H₁₁

- 7-Methyl-4-indanyl-MgBr, IX-II, XIII-I
 C₁₀H₁₁MgCl, * X-I
 5-Tetralyl-MgBr, XI-I
 5,6,7,8-Tetrahydronaphthyl-MgI, X-I

C₁₀H₁₃

- C₆H₅(CH₂)₄MgCl, VI-XIX, XXI-II
 C₆H₅(CH₂)₄MgBr, VI-XVII, XVI-I
 3-CH₃C₆H₄(CH₂)₃MgBr, VI-XVIII
 4-CH₃C₆H₄(CH₂)₃MgX, VIII-III
 CH₃(C₆H₅)CH(CH₂)₂MgBr, VI-XVIII
 2,4-(CH₃)₂C₆H₃(CH₂)₂MgX, VIII-III
 2,5-(CH₃)₂C₆H₃(CH₂)₂MgX, VIII-III
 (-)-CH₃(C₆H₅CH₂)CHCH₂MgBr, XIII-I
 (+)-C₂H₅(C₆H₅)CHCH₂MgCl, XIII-I
 C₂H₅(C₆H₅)CHCH₂MgBr, XIII-I
 4- i -C₃H₇C₆H₄CH₂MgCl, VI-XVII, XVI-I
 4- i -C₃H₇C₆H₄CH₂MgX, VIII-III
 2,4,5-(CH₃)₃C₆H₂CH₂MgCl, XVI-I
 2,4,5-(CH₃)₃C₆H₂CH₂MgX, VIII-III
 2,4,6-(CH₃)₃C₆H₂CH₂MgCl, VI-XVII, IX-II
 4- i -C₄H₉C₆H₄MgBr, VI-XVIII
 3- s -C₄H₉C₆H₄MgBr, VI-XVII
 4- s -C₄H₉C₆H₄MgBr, VI-XVIII, VIII-III, XIII-I
 4- t -C₄H₉C₆H₄MgBr, VI-XVII, VI-XVIII, VIII-III, IX-I, XIII-I
 2-CH₃-4- i -C₃H₇C₆H₃MgBr, XXI-II
 2-CH₃-5- i -C₃H₇C₆H₃MgBr, XIII-I, XVI-I, XVII-IV, XXI-IV
 3-CH₃-6- i -C₃H₇C₆H₃MgBr, XIII-I
 2,3,4,6-(CH₃)₄C₆HMgBr, VI-XVIII, VIII-III
 2,3,5,6-(CH₃)₄C₆HMgBr, 42, VI-XVIII, VIII-III, IX-II, XIII-I, XXI-IV

C₁₀H₁₃O

- C₆H₅O(CH₂)₄MgI, XVI-I
 2-CH₃OCH₂C₆H₄(CH₂)₂MgCl, 42, XXIII-III
 3-CH₃-4-CH₃OC₆H₃(CH₂)₂MgCl, VI-XIX
 C₂H₅(4-CH₃OC₆H₄)CHMgCl, VI-XVIII
 C₂H₅(4-CH₃OC₆H₄)CHMgBr, VI-XVIII
 2-CH₃O(CH₂)₃C₆H₄MgBr, XXIII-III
 2,4,6-(CH₃)₃-3-CH₃OC₆HMgBr, XIII-I

C₁₀H₁₄N

- CH₃(C₆H₅)N(CH₂)₃MgBr, VI-XVIII, VI-XIX
 CH₃(C₆H₅)N(CH₂)₃MgX, VI-XVII

C₁₀H₁₅

- ω -Camphenyl-MgBr, X-I

C₁₀H₁₃O

- n -C₄H₉OCH₂CH=C(CH₃)C≡CMgBr, VI-XVII
 α -Camphoryl-MgBr, VI-XVIII, VI-XIX, XIII-I

C₁₀H₁₆N

- 2,3,4-Triethylpyrryl-MgBr, IX-II

C₁₀H₁₇

- C₁₀H₁₇MgBr, † X-I

*From 2-chloro-1,2,3,4-tetrahydronaphthalene.

†From 1-bromo-(4-methyl-3-cyclohexen-1-yl)propane.

C₁₀H₁₇ (cont.)

3-Bicyclopentyl—MgBr, XVI-I

C₁₀H₁₇MgCl, * VIII-IIIC₁₀H₁₇MgCl, † XX-IIC₁₀H₁₇MgCl, ‡ XX-IIC₁₀H₁₇MgCl, § XX-IIC₁₀H₁₇MgCl, ¶ XX-IIC₁₀H₁₇MgCl, † 11, 154, VIII-III, X-I, XI-I, XII-I, XIV-I XVI-I, XX-II, XXI-IV, XXI-VC₁₀H₁₇MgCl, ** VIII-IIIC₁₀H₁₇MgCl, †† 154, VIII-III, IX-II, XIII-I

Bornyl-MgCl, †† 154, VIII-III, IX-II, XIII-I, XVI-I

Isobornyl-MgCl, §§ 154, VI-XVIII, VIII-III, IX-II, XIII-I

C₁₀H₁₇MgI, ¶¶ XIII-I*n*-C₈H₁₇C≡CMgBr, X-I, XVI-I, XXIII-I**C₁₀H₁₈**C₁₀H₁₈(MgCl)₂, †† XIII-I**C₁₀H₁₉**(CH₂)₅CH(CH₂)₄MgBr, VI-XVII, XIV-ICH₃CH₂CH₂MgBr, *** VI-XVIIC₁₀H₁₉MgBr, ††† XIII-I**C₁₀H₂₀**[—(CH₂)₅MgBr]₂, VIII-III[—(CH₂)₅MgI]₂, XIII-I**C₁₀H₂₁***n*-C₁₀H₂₁MgCl, 32

*From 2-chlorodecalin—either stereoisomer.

†From *trans*-2-chlorodecalin.‡From chlorinated *trans*-decalin.§From chlorinated *cis*-decalin.¶From chlorinated *cis*-β-decalin.

‡‡From pinene hydrochloride.

**From bornyl chloride.

††From (+)-α-pinene hydrochloride; Rivière, *Ann. chim.*, [12], 1, 157-231 (1946), concludes that this reagent is an equimolecular mixture of bornyl- and isobornylmagnesium chlorides.

‡‡Prepared by refluxing in xylene for three hours at *ca.* 140° the Grignard reagent from (+)-α-pinene hydrochloride.

§§Prepared by partial (*ca.* 66%) carbonation of the Grignard reagent from (+)-α-pinene hydrochloride.

¶¶From bornyl iodide.

‡‡From 1,8-dichloro-*p*-menthane.

***R = 4-methyl-3-cyclohexen-1-yl.

†††From 5-bromo-*p*-menthane.**C₁₀H₂₁ (cont.)***n*-C₁₀H₂₁MgBr, 32, VI-XVII, VI-XVIII, VIII-III, X-I, XII-I, XIII-I, XVI-I, XXI-V, XXII-I*n*-C₁₀H₂₁MgI, 32*i*-C₃H₇(CH₂)₃CH(CH₃)(CH₂)₂MgX, VI-XIX**C₁₁H₈O₂**1-C₁₀H₇CH(CO₂MgCl)MgCl, ††† XIII-I**C₁₁H₉**1-C₁₀H₇CH₂MgCl, 16, 30, VI-XVII, VI-XVIII, VIII-III, IX-II, XIII-I, XVII-I, XIX-I, XXI-I2-C₁₀H₇CH₂MgCl, VI-XVII, XVII-I2-C₁₀H₇CH₂MgBr, VI-XVII, IX-II, XIII-I, XVII-I2-CH₃C₁₀H₆-1-MgBr, VI-XVII, VI-XVIII, VIII-IV, IX-I, X-I, XIII-I4-CH₃C₁₀H₆-1-MgBr, 42, VI-XVII, VI-XVIII, VI-XIX, XI-I5-CH₃C₁₀H₆-1-MgBr, XXI-I8-CH₃C₁₀H₆-1-MgBr, VI-XVII, VI-XVIII, X-I, XI-I, XXI-I1-CH₃C₁₀H₆-2-MgI, VI-XVIII**C₁₁H₉ClO**2,4-(CH₃)₂-3-Cl-6-CH₃OC₆HC≡CMgBr, XIII-I**C₁₁H₉O**2-CH₃OC₁₀H₆-1-MgBr, VIII-III, XI-I, XIII-I4-CH₃OC₁₀H₆-1-MgBr, VI-XVII, XIII-I, XIV-I6-CH₃OC₁₀H₆-1-MgI, 42, VI-XVII, X-I, XIV-I6-CH₃OC₁₀H₆-2-MgBr, 42, VI-XIX, X-I, XI-I, XIII-I, XX-II**C₁₁H₁₂ClO₂**[2,4-(CH₃)₂-3-Cl-6-CH₃OC₆HCOCH₂]⁻MgBr, † XIII-I**C₁₁H₁₂O₂**[4-*i*-C₃H₇C₆H₄CH(CO₂MgCl)]⁻MgX, † XIII-I**C₁₁H₁₃**

2-Phenylcyclopentyl-MgBr, XIII-I

3-Phenylcyclopentyl-MgBr, XIII-I

4-(CH₂)₄CHC₆H₄MgBr, VIII-III, XIV-I

2-Methyl-5,6,7,8-tetrahydronaphthyl-1-MgBr, XIII-I

C₁₁H₁₃O[2,4,6-(CH₃)₃C₆H₂COCH₂]⁻MgBr, † XIII-I**C₁₁H₁₄**H₂C[(CH₂)₃C≡CMgBr]₂, XIII-I

‡‡‡In the opinion of Schlenk, Hilleman, and Rodloff, *Ann.*, 487, 135-54 (1931), this "Grignard reagent" should be formulated as an enolate.

C₁₁H₁₅

- C₆H₅(CH₂)₅MgBr, VI-XVIII, XIII-I, XVI-I
 2,4-(CH₃)₂C₆H₃(CH₂)₃MgX, VIII-III
 2,5-(CH₃)₂C₆H₃(CH₂)₃MgX, VIII-III
 C₂H₅(C₆H₅)CH(CH₂)₂MgBr, VI-XVII
 3-*i*-C₃H₇C₆H₄(CH₂)₂MgBr, VI-XIX
 4-*i*-C₃H₇C₆H₄(CH₂)₂MgX, VIII-III
 C₆H₅(CH₂)₂CH(CH₃)CH₂MgBr, VI-XVII
 4-CH₃C₆H₄(CH₃)₂CCH₂MgCl, XXI-V
 4-*n*-C₄H₉C₆H₄CH₂MgCl, XVI-I
 4-*t*-C₄H₉C₆H₄CH₂MgCl, XVI-I
 2-CH₃-4-*i*-C₃H₇C₆H₃CH₂MgCl, XVI-I
 2-CH₃-5-*i*-C₃H₇C₆H₃CH₂MgCl, XVI-I
 2-CH₃-5-*i*-C₃H₇C₆H₃CH₂MgX, VIII-III
t-C₄H₉(C₆H₅)CHMgBr, XIII-I
 3-*n*-C₃H₁₁C₆H₄MgBr, VI-XVIII
 4-*t*-C₃H₁₁C₆H₄MgBr, VIII-III
 2-CH₃-4-*t*-C₄H₉C₆H₃MgBr, XIV-I
 (CH₃)₅C₆MgCl, VI-XVIII, XVI-I
 (CH₃)₅C₆MgBr, 38-40, 42, VI-XVII, VI-XVIII, VIII-III, IX-II, XIII-I, XVI-I, XXI-IV

C₁₁H₁₅O

- C₆H₅O(CH₂)₅MgI, VI-XVII, XVI-I, XX-II
 2-CH₃O-5-*t*-C₄H₉C₆H₃MgBr, XIV-I
 2-CH₃-4-CH₃O-5-*i*-C₃H₇C₆H₂MgBr, X-I

C₁₁H₁₅O₂

- 2,4,5-(CH₃)₃-3,6-(CH₃O)₂C₆MgBr, 42, XIV-I

C₁₁H₁₅N

- 2,3-Diethyl-4-*n*-propylpyrrol-MgBr, IX-II

C₁₁H₁₉

- n*-C₈H₁₉C≡CMgBr, VIII-III, X-I, XXIII-I

C₁₁H₂₃

- n*-C₁₁H₂₃MgBr, XIII-I, XXI-V
n-C₁₀H₂₁CH₂MgBr, IX-I
i-C₃H₇(CH₂)₈MgCl, 32
i-C₃H₇(CH₂)₈MgBr, 32
i-C₃H₇(CH₂)₈MgI, 32
 CH₃(*n*-C₄H₉)CH(CH₂)₅MgBr, VI-XVIII
 CH₃(*n*-C₆H₁₃)CH(CH₂)₃MgBr, IX-I
 (+)—CH₃(*i*-C₆H₁₃)CH(CH₂)₃MgBr, VI-XVIII
 CH₃(*n*-C₇H₁₅)CH(CH₂)₂MgBr, VI-XVIII
i-C₄H₉(*n*-C₆H₁₃)CHMgBr, VI-XVIII

C₁₁H₂₄N

- (*n*-C₄H₉)₂N(CH₂)₃MgCl, VI-XVII, VI-XVIII, VI-XIX

C₁₂H₇

- 1-C₁₀H₇C≡CMgBr, X-I, XXIII-I
 2-C₁₀H₇C≡CMgBr, VI-XVIII

C₁₂H₇O

- 1-Dibenzofuryl-MgBr, XIII-I, XX-II

C₁₂H₇O (cont.)

- 2-Dibenzofuryl-MgBr, XX-II
 4-Dibenzofuryl-MgBr, 24, XIII-I

C₁₂H₈

- (—C₆H₄-3-MgBr)₂, XIII-I

C₁₂H₈Br

- 3-BrC₆H₄C₆H₄-3-MgBr, XIII-I

C₁₂H₈Cl

- 2-(*p*-ClC₆H₄)C₆H₄MgI, VI-XVIII

C₁₂H₈N

- Carbazolyl-MgI, 86

C₁₂H₈O₂

- [1-C₁₀H₇CH(CO₂MgCl)]⁻MgX,⁺ XIII-I
 [2-C₁₀H₇CH(CO₂MgCl)]⁻MgX,⁺ XIII-I

C₁₂H₉

- 2-C₆H₅C₆H₄MgBr, VI-XVII, XVI-I
 2-C₆H₅C₆H₄MgI, VI-XVII, VI-XVIII, VII-II, XII-I, XIII-I, XIV-I, XIX-II
 3-C₆H₅C₆H₄MgBr, VI-XIX, VIII-III, XIII-I
 4-C₆H₅C₆H₄MgBr, 10, VI-XVIII, VII-II, VIII-III
 4-C₆H₅C₆H₄MgI, VI-XVIII, VIII-III, IX-II
 4-C₆H₅C₆H₄MgX, XX-II
 3-Acenaphthenyl-MgI, 42, XIV-I
 5-Acenaphthenyl-MgBr, VI-XVIII

C₁₂H₉O

- 2-C₆H₅OC₆H₄MgI, VI-XIX, VII-II
 4-C₆H₅OC₆H₄MgCl, XX-II
 4-C₆H₅OC₆H₄MgBr, V-I, VIII-III, XIV-I

C₁₂H₁₁

- 1-C₁₀H₇(CH₂)₂MgCl, VI-XIX
 2-C₂H₅C₁₀H₆-1-MgBr, XIII-I
 2,3-(CH₃)₂C₁₀H₅-1-MgBr, XIII-I
 2,7-(CH₃)₂C₁₀H₅-1-MgBr, XXI-I
 3,4-(CH₃)₂C₁₀H₅-1-MgBr, 42, VI-XIX
 4,7-(CH₃)₂C₁₀H₅-1-MgBr, XIII-I

C₁₂H₁₁O

- C₆H₅OCH₂CH=C(CH₃)C≡CMgBr, VI-XVII
 6-C₂H₅OC₁₀H₆-2-MgBr, X-I, XIII-I
 4-CH₃O-6-CH₃C₁₀H₅-1-MgBr, XIV-I

C₁₂H₁₃

- 2-(1-Tetralylidene)ethyl-MgBr, VI-XIX

C₁₂H₁₄ClO₂

- [2,4-(CH₃)₂-3-Cl-6-CH₃OC₆HCOCH-CH₃]⁻MgBr,⁺ XIII-I
 [2,4-(CH₃)₂-3-Cl-6-C₂H₅OC₆HCO-CH₂]⁻MgBr,⁺ XIII-I

C₁₂H₁₅

- β-(1-Tetralyl)ethyl-MgCl, XI-I
t-C₄H₉(C₆H₅)C=CHMgBr, XIII-I
 4-(CH₂)₅CHC₆H₄MgBr, VI-XVII, VIII-III, XIII-I, XIV-I
 4-(CH₂)₅CHC₆H₄MgI, VIII-III, XIII-I
 7-Isopropyl-4-indanyl-MgBr, IX-II

- C₁₂H₁₅O**
[2,4,6-(CH₃)₃C₆H₂COCH(CH₃)₂]⁻MgBr, ⁺XIII-I
- C₁₂H₁₅O₂**
[2,4-(CH₃)₂-6-CH₃OC₆H₂COCH(CH₃)₂]⁻MgBr, ⁺XIII-I
- C₁₂H₁₇**
4-*i*-C₃H₇C₆H₄(CH₂)₃MgCl, XXI-I
4-*i*-C₃H₇C₆H₄(CH₂)₃MgX, VIII-III
2-CH₃-5-*i*-C₃H₇C₆H₃(CH₂)₂MgX, VIII-III
t-C₅H₁₁C₆H₄CH₂MgCl, XVI-I
2,6-(CH₃)₂-4-*i*-C₄H₉C₆H₂MgBr, IX-II, XXI-I
2,4,6-(C₂H₅)₃C₆H₂MgBr, XIII-I
- C₁₂H₁₉**
2-(1-Decalylidene)ethyl-MgBr, VI-XIX
- C₁₂H₁₉Si**
4-(C₂H₅)₂SiC₆H₄MgBr, 30, VI-XVII
- C₁₂H₂₅**
n-C₁₂H₂₅MgCl, VI-XVII, XVI-I, XXII-I, XXIII-I
n-C₁₂H₂₅MgBr, VI-XVIII, VI-XIX, VIII-III, IX-I, X-I, XIII-I, XVI-I, XIX-VIII, XXI-II, XXI-V, XXII-I
n-C₃H₇(*n*-C₆H₁₇)CHMgI, VI-XVII
- C₁₃H₉**
9-Fluorenyl-MgBr, 71, VI-XVIII, VIII-III, IX-II, XIII-I, XVI-I
- C₁₃H₉O₂**
2-Methoxy-1-dibenzofuryl-MgBr, XIII-I, XVI-I
2-Methoxy-3-dibenzofuryl-MgBr, XIII-I, XVI-I, XX-II
- C₁₃H₁₀O₄S₂**
(C₆H₅SO₂)₂C(MgBr)₂, IX-II, XVI-I
- C₁₃H₁₁**
(C₆H₅)₂CHMgCl, VIII-III, XIII-I, XXI-I
(C₆H₅)₂CHMgBr, 24, X-I, XIX-V
2-C₆H₅CH₂C₆H₄MgBr, VI-XIX, VIII-III, IX-II
4-*n*-C₇H₁₃C₆H₄MgBr, XXI-II
- C₁₃H₁₁O**
2-*p*-CH₃C₆H₄OC₆H₄MgI, VI-XIX
[2-CH₃C₁₀H₆-1-COCH₂]⁻MgBr, ⁺XIII-I
- C₁₃H₁₂NS**
10-Ethyl-3-phenothiazinyl-MgI, XIII-I
- C₁₃H₁₃O**
6-CH₃OC₁₀H₆-1-CH₂CH₂MgCl, VI-XIX
- C₁₃H₁₅Br₂O₂**
[2,4,6-(CH₃)₃-3,5-Br₂C₆COC(CH₃)₂]⁻MgBr, ⁺XIII-I
- C₁₃H₁₆ClO₂**
[2,4-(CH₃)₂-3-Cl-6-C₃H₅OC₆HCOCH(CH₃)₂]⁻MgBr, ⁺XIII-I
- C₁₃H₁₇**
β-(5-Methyl-1,2,3,4-tetrahydro-1-naphthyl)ethyl-MgBr, VI-XIX
- C₁₃H₁₇ (cont.)**
β-(7-Methyl-1,2,3,4-tetrahydro-1-naphthyl)ethyl-MgBr, VI-XIX
4-(CH₂)₅CHC₆H₄CH₂MgCl, XIII-I, XX-II
- C₁₃H₁₇O**
[2,4,6-(CH₃)₃C₆H₂COC(CH₃)₂]⁻MgBr, ⁺XIII-I
- C₁₃H₁₉O₂**
2,4,5-(CH₃)₂-3,6-(CH₃O)₂C₆(CH₂)₂-MgCl, VI-XVIII
- C₁₃H₂₅O**
[(*t*-C₄H₉CH₂)₂CHCOCH₂]⁻MgBr, ⁺XIII-I
[*t*-C₄H₉CH₂C(CH₃)(*t*-C₄H₉)COCH₂]⁻MgBr, ⁺XIII-I
- C₁₃H₂₇**
n-C₁₃H₂₇MgBr, XXI-V
- C₁₄H₉**
9-Anthryl-MgBr, 16, 29, VI-XVIII, VI-XIX, X-I, XIII-I, XVI-I, XXIII-I
9-Phenanthryl-MgBr, 29, VI-XVII, VI-XVIII, VI-XIX, VIII-III, IX-11, X-I, XI-I, XIII-I, XIV-I, XVI-I, XX-II
- C₁₄H₉O**
2,2,5,7,8-Pentamethyl-6-chromanyl-MgBr, XX-II
- C₁₄H₁₁**
(C₆H₅)₂C=CHMgBr, VI-XVII, VI-XVIII, VI-XIX, VIII-III
- C₁₄H₁₃**
2-C₆H₅C₆H₄(CH₂)₂MgBr, XIII-I, XIV-I
C₆H₅(2-CH₃C₆H₄)CHMgCl, X-I
4-C₆H₅(CH₂)₂C₆H₄MgBr, XVI-I
- C₁₄H₁₃O**
4-C₆H₅CH₂OC₆H₄CH₂MgCl, 30
[2-CH₃C₁₀H₆-1-COCH(CH₃)₂]⁻MgBr, ⁺XIII-I
- C₁₄H₁₇O**
2,2,5,7,8-Pentamethyl-6-chromanyl-MgBr, 42
- C₁₄H₁₉**
β-(5,6-Dimethyl-1,2,3,4-tetrahydro-1-naphthyl)ethyl-MgBr, VI-XIX
- C₁₄H₂₇O**
[*t*-C₄H₉CH₂C(CH₃)(*t*-C₄H₉)COCH(CH₃)₂]⁻MgBr, ⁺XIII-I
- C₁₄H₂₉**
n-C₁₄H₂₉MgCl, XXII-I
n-C₁₄H₂₉MgBr, VI-XVII, VI-XVIII, IX-I, XIII-I, XVI-I, XXI-V, XXII-I, XXIII-II
n-C₁₄H₂₉MgX, VI-XIX
- C₁₅H₁₃**
C₆H₅(4-CH₃C₆H₄)C=CHMgBr, 12
- C₁₅H₁₅O₂S**
C₆H₅CH₂(4-CH₃C₆H₄SO₂)CHMgI, * 73

*This compound is undoubtedly analogous to the enolates that behave as true Grignard reagents.

- $C_{15}H_{15}O_4S_2$
 $(4-CH_3C_6H_4SO_2)_2CHMgBr$, * 73-74
 $C_{15}H_{17}$
 $3,8-(CH_3)_2-5-i-C_3H_7C_{10}H_4-2-MgBr$,
 VIII-III
 $C_{15}H_{20}O$
 $R(CH_3)(BrMgO)CC \equiv CMgBr$,† XVI-I
 $C_{15}H_{23}$
 $2,4,6-(i-C_3H_7)_3C_6H_2MgBr$, IX-II
 $C_{15}H_{29}$
 $R(CH_2)_2CH(CH_3)(CH_2)_2MgBr$,† XVI-I
 $C_{15}H_{29}O$
 $[i-C_4H_9CH_2C(CH_3)(i-C_4H_9)COC-$
 $(CH_3)_2]^-MgBr$,‡ XIII-I
 $C_{15}H_{31}$
 $n-C_{15}H_{31}MgBr$, XIII-I, XXI-V
 $CH_3(n-C_{10}H_{21})CH(CH_2)_3MgBr$, IX-I
 $C_{15}H_{31}O$
 $i-C_6H_{13}CH(CH_3)CH(CH_2CH_2OC_2H_5)-$
 $CH(CH_3)MgCl$, XIII-I
 $C_{16}H_{11}O$
 $2,5-Diphenyl-3-furyl-MgBr$, IX-II, X-I,
 XI-I, XIII-I
 $C_{16}H_{13}$
 $9-Phenanthryl-CH_2CH_2MgCl$, VI-XIX
 $C_{16}H_{17}$
 $2-[2,4,6-(CH_3)_3C_6H_2CH_2]C_6H_4MgBr$,
 VI-XVIII, XVI-I
 $C_{16}H_{33}$
 $n-C_{16}H_{33}MgCl$, 32
 $n-C_{16}H_{33}MgBr$, 32, VI-XVII, VI-XVIII,
 XVI-I, XX-II, XXI-V
 $n-C_{16}H_{33}MgI$, 32, XIII-I
 $n-C_{16}H_{33}MgX$, VI-XIX
 $n-C_{11}H_{23}CH(CH_3)(CH_2)_3MgCl$, XIV-I
 $i-C_6H_{13}CH(CH_3)(CH_2)_3CH(CH_3)(CH_2)_2-$
 $MgBr$, VI-XVII
 $C_{17}H_{23}$
 $t-C_4H_9(C_6H_5)(t-C_4H_9C \equiv C)CMgBr$, IX-
 II, XIII-I
 $C_{17}H_{35}$
 $n-C_{17}H_{35}MgBr$, VI-XVII
 $C_{18}H_{13}$
 $C_6H_5(1-C_{10}H_7)C \equiv CHMgBr$, 12, VI-
 XVIII
 $C_{18}H_{19}$
 $9-Neopentyl-9-fluorenyl-MgCl$, 89
 $C_{18}H_{33}$
 $n-C_{16}H_{33}C \equiv CMgBr$, VI-XVIII
 $C_{18}H_{37}$
 $n-C_{18}H_{37}MgCl$, VI-I, VI-XVII, XXII-I

- $C_{18}H_{37}$ (cont.)
 $n-C_{18}H_{37}MgBr$, 30, VI-XVIII, VI-XIX,
 IX-I, XIII-I
 $n-C_{18}H_{37}MgX$, XVI-I
 $C_{19}H_{13}$
 $C_6H_5(C_{12}H_8 \equiv)CMgX$, * 87, XIII-I
 $C_{19}H_{15}$
 $(C_6H_5)_3CMgCl$, 160, VI-XVII, VI-XVIII,
 VII-II, VIII-III, IX-II, XIII-I, XX-II
 $(C_6H_5)_3CMgBr$, 31, 87, 160, IX-II, XIII-
 I, XVI-I, XIX-I
 $(C_6H_5)_3CMgI$, 86-87
 $2-[C_6H_5)_2CH]C_6H_4MgBr$, VI-XIX
 $C_{19}H_{19}$
 $t-C_4H_9C \equiv C(C_6H_5)_2CMgBr$, XIII-I
 $C_{19}H_{27}$
 $(t-C_4H_9C \equiv C)_3CMgBr$, XIII-I
 $C_{20}H_{13}$
 $1-Phenyl-2-o-biphenylenevinyl-MgBr$,
 VI-XIX, IX-II, XIII-I
 $10-Phenyl-9-anthryl-MgBr$, 42, XIII-
 I, XXIII-I
 $C_{20}H_{14}Cl$
 $4-ClC_6H_4(C_6H_5)C \equiv C(C_6H_5)MgBr$,
 XIII-I
 $C_{20}H_{15}$
 $4-C_6H_5C_6H_4CH \equiv C(C_6H_5)MgBr$, XIII-I
 $(C_6H_5)_2C \equiv C(C_6H_5)MgBr$, 30, VI-
 XVII, VI-XVIII, VI-XIX, IX-II, XIII-
 I, XXI-IV, XXIII-I
 $C_{20}H_{16}$
 $9,10-Anthrylenebis(phenyl-4-MgBr)$,
 42
 $C_{20}H_{41}$
 $i-C_3H_7(CH_2)_3[CH(CH_3)(CH_2)_3]CH-$
 $(CH_3)(CH_2)_2MgX$, VI-XIX
 $C_{21}H_{15}$
 $(1-C_{10}H_7)_2CHMgCl$, XIII-I
 $(2-C_{10}H_7)_2CHMgCl$, XIII-I
 $C_{21}H_{17}$
 $C_6H_5(4-CH_3C_6H_4)C \equiv C(C_6H_5)MgBr$,
 XIII-I
 $C_{21}H_{17}O$
 $C_6H_5(4-CH_3OC_6H_4)C \equiv C(C_6H_5)MgBr$,
 XIII-I
 $C_{21}H_{19}O_2S$
 $(C_6H_5)_2CH(4-CH_3C_6H_4SO_2)CHMgI$,§ 73
 $C_{22}H_{19}$
 $(4-CH_3C_6H_4)_2C \equiv C(C_6H_5)MgBr$, XIII-I
 $C_{22}H_{19}O_2$
 $(4-CH_3OC_6H_4)_2C \equiv C(C_6H_5)MgBr$,
 XIII-I
 $C_{22}H_{21}$
 $(4-CH_3C_6H_4)_3CMgCl$, XIII-I
 $C_{22}H_{45}$
 $n-C_{22}H_{45}MgBr$, XIII-I

*This compound is undoubtedly analogous to the enolates that behave as true Grignard reagents.

†R = β -(2, 6, 6-trimethyl-1-cyclohexenyl)vinyl.

‡R = 2,2,6-trimethylcyclohexyl.

§ $C_{12}H_8 \equiv$ = o-biphenylene; X = Br, I.

$C_{24}H_{17}$ 2,4,6-(C_6H_5)₃ C_6H_2MgBr , VI-XVII, IX-II, XIII-I $C_{26}H_{16}$ $C_{26}H_{16}(MgBr)_2$, * XIII-I $C_{26}H_{25}$ 1-Neopentyl-2,3-diphenyl-1-indenyl- $MgCl$, 89 $C_{26}H_{53}$ n - $C_{26}H_{53}MgX$, VI-XIX $C_{27}H_{45}$ 3-Cholesteryl- $MgCl$, VI-XVII, XIII-I, XX-II $C_{30}H_{23}$ $C_{12}H_8 = [t-C_4H_9(C_{12}H_8 =)C]CMgCl, \dagger$
88 $C_{30}H_{31}$ 1-Neopentyl-2,3,4,5-tetraphenyl-1-cyclopentadienyl- $MgCl$, 89-90*From 9,10-bis-*p*-bromophenylanthracene. $\dagger C_{12}H_8 =$ = *o*-biphenylene. $C_{32}H_{27}$ $C_{12}H_8 = [t-C_4H_9(C_{12}H_8 =)CCH = CH]CMgCl, \dagger$ 89 $C_{33}H_{22}Cl$ $C_{12}H_8 = [4-ClC_6H_4CH_2(C_{12}H_8 =)C]CMgCl, \dagger$ 88 $C_{33}H_{23}$ $C_{12}H_8 = [C_6H_5CH_2(C_{12}H_8 =)C]CMgCl, \dagger$ 88, XVI-I $C_{33}H_{29}$ 1-Benzyl-2,3,4,5-tetraphenyl-1-cyclopentadienyl- $MgCl$, 89-90 $C_{35}H_{24}Cl$ $C_{12}H_8 = [4-ClC_6H_4CH_2(C_{12}H_8 =)CCH = CH]CMgCl, \dagger$ 89 $C_{35}H_{25}$ $C_{12}H_8 = [C_6H_5CH_2(C_{12}H_8 =)CCH = CH]CMgCl, \dagger$ 89 $\dagger C_{12}H_8 =$ = *o*-biphenylene.

General Index

Acetals:

- as sources of ethers, 1041-1045
- prep'n from orthoformates, 561, 586-591

Acetals and ketals—reactions with G. r's., 1041-1045

Acetoacetic ester-type condens'ns, 564-567

Acetomesitylene enolate, 139-140, 180

Acetone as inhibitor in G. r. prep'n, 13

Acetylenic Grignard reagents:

- condens'n with alkyl halides, 1053-1054
- prep'n of, 66-70

Acids (carboxylic) from CO₂, 913-948

Acids (carboxylic) and their salts:

- reactions with G. r's., 948-960
- t*-alcohol form'n, 948-949
- enolization, 949-950
- ketone form'n, 948-949

Acids (dithiocarboxylic) from CS₂, 1286-1287

Acids (keto) from anhydrides, 847, 849, 851

Acids (Lewis):

- G. r. components as, 111, 174
- in cleavage of oxirane ring, 964-965
- in cleavage of oxirane ring, 964-965
- in G. r. enoliz'n of ketones, 174-176

Acids (sulfinic) from SO₂, 1288-1289

Acids (thiocarboxylic) from COS, 1288

Acid-titration of Grignard reagents, 94-95

Activation of magnesium:

- continuous (*see* Entrainment), 38-45
- electrolytic, 8
- mechanical, 7,

Activation of magnesium by:

- bromine, 10
- β -bromoethyl ether, 11
- ethyl bromide, 10
- ethyl iodide, 11
- ethylmagnesium bromide, 10, 11
- iodine, 8
- magnesium halides, 9
- magnesium bromide, 10
- magnesium iodide, 9
- methyl iodide, 11
- methylene iodide, 11

Activators and inhibitors in G. r. prep'n, 8

Active hydrogen:

- groups containing, 1169-1171
- Zerewitinoff det'n of, 1166-1198

Active hydrogen compounds:

- ammonia, amines, hydrazines as, 1255-1256

- as sources of G. r's., 66-86

- enolizable ketones as, 166-167

- hydroxylamines as, 1235-1236

- isonitroso compounds as, 1221

- ketimines as, 1208

- oximes as, 1217

- phosphines as, 1335

- primary amines as, 141, 1255-1256

- semicarbazones as, 1222

- "unreactive" amides as, 876

Acyclic ketones (T. VI-XVIII), 310-452

Acyl radicals—coupling of, 126-127

Addition of G. r's. to olefins, 87-90

1,2-Add'n of G. r's. to conj. carbonyl systems:

- mechanism of, 223-224

- suppression of, 221

1,2-, 1,4-Add'n of G. r's. to conj. carbonyl systems, 196-234

- as competitive reactions, 220, 225

- constitutional factors affecting, 224-228

- effect of cuprous halides on, 219-221

- facilitation of 1,4-add'n, 219-221

- suggested research precautions, 227-228

- T. VI-XVI, 198-218

1,2-, 1,4-Add'n of G. r's. to quinones, 529-531

1,4-Add'n of G. r's. to:

- conj. carbonyl systems:

- involving aromatic nuclei, 228-232

- mechanism of, 221-223

- suppression of, 223-224

- ketimines, 1209-1210

- unsat'd amides, 875

- unsat'd carboxylic esters, 563-564

- unsat'd epoxides, 975-976

- unsat'd nitriles, 782-783

- unsat'd sulfones, 1298

1,4-Add'n (transannular) of G. r's. (*see* 1,6-Add'n)

1,6-Add'n of G. r's. to:

- conj. carbonyl systems, 234-238

- involving cleavages, 238

- mechanism of, 237-238

- Agitation of reaction mixture in G. r. prep'n, 19
- Alcohols (amino) from α -halo amides, 874
- Alcohols by oxid'n of G. r's. 1264-1273
- Alcohols (cyclic) from cyclic ketones, 146, 453-528
- Alcohols—prep'n from:
 carbonyl comp'ds, 145-146, 240-309, 310-452, 453-528
 carboxylic esters, 549, 557-560, 579-580, 581-586, 591-674
 epoxides, 976-977, 978-1012
 ethylene oxide, 976-977, 978-987
 trimethylene oxide, 1031-1032
- Alcohols (primary)—prep'n from:
 ethylene oxide, 961-965, 966-967, 978-987
 formaldehyde, 145, 240-245
- Alcohols (secondary)—prep'n from:
 aldehydes, 145-146, 249-309
 formates, 549, 558, 578-580, 581-586
- Alcohols (tertiary)—prep'n from:
 carbon dioxide, 913
 carbonates, 561, 580-581
 carbonyl sulfide, 1288
 carboxylic anhydrides, 846-847
 chloroformates, 560, 579
 esters, 549, 557-560, 591-674
 ketones (acyclic), 146, 310-452
 ketones (cyclic), 146, 453-528
 nitriles, 772-773
- Alcohols (vinyl):
 from enolate hydrolyses, 222, 238-239
 from G. r.-ketene reductions, 239
- Aldazines—reactions with G. r's., 1211-1212
- Aldehydes and ketones:
 alkoxide reduction of, 158-160, 164
 as oxidizing agents, 158-160, 164
 complex formation with G. r's., 138-142
 cross-condensation of, 178, 180
 Grignard reductions of, 147-166
 magnesian halide reduction of, 160-166
 Meerwein reduction of, 158-160, 164
 reactions with G. r's., 138-238
 "normal" addition, 138-142
 reduction, 147-157
- Aldehydes and ketones (α -halo):
 reactions with G. r's., 181-196
 enolization, 181, 195-196
 halogen replacement, 182-189
 "normal" addition, 182
 reductive enolization, 189-196
- Aldehydes as inhibitors in G. r. prep'n, 13
- Aldehydes—prep'n from:
 formamides, 870
 formates, 561, 582-586
 orthoformates, 561, 586-591
- Aldehydes—reactions with G. r's. (T. VI-XVII), 240-309
- Aldimines—reactions with G. r's., 1204-1208
- Aldolization and ketolization, 176-181
 mechanism of, 179
- Alkoxides as reducing agents, 158-160, 164
 asymmetric, 160
- Alkoxyamines—reactions with G. r's., 1235-1237
- Alkyl dihalides—dehalogenation by G. r's., 1053
- Alkyl halides—reactions with G. r's., 1046-1132
 dehydrohalogenation, 1052-1053
 mechanisms of, 1048-1053
 "normal" condensation, 1046-1052
- Alkyl hydroperoxides by oxid'n of G. r's., 1266-1267
- Alkyl sulfates:
 as sources of G. r's., 90-91, 1277
 reactions with G. r's., 1277-1278, 1279-1281
- t*-Alkylamines from nitriles, 772-773
- N*-Alkylmorpholines as solvents in G. r. prep'n, 50
- Alloys (magnesium), 12
- Allylic Grignard reagents:
 "abnormal" reactions of, 1145-1157
 constitution of, 60, 1156
 preparation of, 17, 18, 24, 27, 28, 47-48
- Allylic halides—reactions with G. r's., 1050-1051, 1157-1158
- Allylic rearrangements in Grignard reactions, 1133-1165
 allylic co-reactants, 1157-1165
 allylic Grignard reagents, 1145-1157
 arylmethyl Grignard reagents, 1133-1145, 1278
- Allylmagnesium halides:
 constitution of, 60, 1156
 prep'n of, 17, 18, 24, 27, 28, 47-48
- Amides (carboxylic):
 as sources of amines, 871-872
 as sources of imides, 872-873
 as sources of ketones, 870
 as sources of nitriles, 870-871
 condensations of, 875-876
 from nitriles, 774
 reactions with G. r's., 870-876
- Amides (α -halo):
 as sources of amino alcohols, 874
 reductive dehalogenation of, 873-874

- Amides (unreactive), 876
Amides (α,β -unsaturated)—1,4-add'n of G. r's. to, 875
Amidines from cyanamides, 788
Amines from amides, 871-872
Amines (*t*-alkyl) from nitriles, 772-773
Amines (primary):
 as "active" hydrogen comp'ds, 141, 1255-1256
 from alkoxyamines, 1236-1237
Amines (secondary) from aldimines, 1204-1208
Amines (tertiary):
 as "catalysts" in G. r. prep'n, 50-53
 as complex-formers with G. r's., 142, 156
 as solvents in G. r. prep'n, 49
Amino alcohols from α -halo amides, 874
Ammonia, amines, hydrazines, and triazenes—reactions with G. r's., 1255-1259
Analytical evaluation of G. r's., 92-95
 acid-titration, 94-95
 gas-analysis, 94
 iodimetric, 92-94
Anethole hydrobromide as source of hexestrol, 1057-1058
Anhydrides (carboxylic) as sources of:
 t-alcohols, 846-847
 keto acids, 847, 849, 851
 ketones, 846-847, 851
 phthalides, 848, 851
Anhydrides (carboxylic)—reactions with G. r's., 846-869
 mechanism of, 849-851
Anilides from phenyl isocyanate, 1199-1204
Anilines (*N,N*-disubstituted) from phenyl isocyanate, 1200
Anils (keto) (*see* Ketimines)
Apparatus for G. r. prep'n:
 classical, 22
 cyclic reactor, 23
 mechanical activation, 7
Aromatic ethers as sources of G. r's., 74
Arylmagnesium halides—reactions with aurous chloride carbonyl, 119
Arylmethylmagnesium halides:
 "abnormal" reactions of, 1133-1145
 ortho condensations, 1133, 1134-1140, 1141-1145
 para condensations, 1135-1137, 1145
Association of G. r. components with:
 t-amines, 142, 156
 carbonyl comp'ds, 138-142, 223, 1141
Association of G. r. components with:
 (*cont'd*)
 each other, 102-104
 ethers, 99-102, 106, 156, 1023
 nitriles, 142, 767-769
Asymmetric Grignard reagents:
 as asymmetric reducing agents, 154-157
Asymmetric reaction media, 155
Asymmetric reduction:
 of pinacolin by (+) - $\text{CH}_3(\text{C}_2\text{H}_5)\text{-CHCH}_2\text{MgCl}$, 155
 of unsymmetrical ketones:
 by asymmetric alkoxides, 160
 by asymmetric G. r's., 154-157
Aurous chloride carbonyl—reactions with aryl G. r's., 119
Azides:
 configuration of, 1226
 reactions with G. r's., 1226-1227
Azo compounds:
 from nitroso compounds, 1228-1229
 reactions with G. r's., 117, 1249-1251
Azoxy compounds—reactions with G. r's., 1232
Barbier synthesis, 3
Beckmann-type rearrangements in oxime reactions, 1218-1221
Behavior of free radicals in solution, 124-126
Benzophenone—red'n by RMgX (T. VI-II), 153
Benzopyrylium salts from lactones, 576
Benzyl G. r's. and their analogs:
 "abnormal" reactions of, 1133-1145, 1278
 ortho condensations, 1133, 1134-1140, 1141-1145
 para condensations, 1135-1137, 1145, 1278
Bromine as activator in G. r. prep'n, 10
 β -Bromoethyl ether as activator in G. r. prep'n, 11
Bromoform as inhibitor in G. r. prep'n, 13
Butenyl Grignard reagents:
 "abnormal" reactions of, 1145-1157
 constitution of, 60, 1156-1157
 prep'n of, 24, 47-48
Byproducts of carboxylic ester reactions, 572-573
Cadmium and zinc salts in ketone prep'n from carbonyl halides, 713-724
Camphor (rate of enolization of), 167-168
Cannizzaro reaction, 181
Carbazolyl Grignard reagents, 86

- Carbinols (*see* Alcohols)
- Carbodiimides—reactions with G. r's., 1213
- Carbon dioxide:
as inhibitor in G. r. prep'n, 14
as source of *t*-alcohols, 913
as source of carboxylic acids, 913-948
as source of ketones, 913-914, 917, 918, 919, 920
reactions with G. r's., 913-948
- Carbon disulfide:
as inhibitor in G. r. prep'n, 13
reactions with G. r's., 1286-1288
- Carbon monoxide—reactions with G. r's., 910-913
- Carbon suboxide—reactions with G. r's., 909
- Carbon tetrachloride as inhibitor in G. r. prep'n, 13
- Carbonyl halides:
"abnormal" reactions of, 730-731
coupling reactions of, 126-127, 164, 727-729
ether cleavage by, 727
reactions with G. r's., 709-766
reduction by G. r's., 725-727
- Carbonyl halides (T. IX-II), 734-766
- Carbonyl halides (α -halo)—reactions with G. r's., 731-732
- Carbonyl halides (other than RCOX)—reactions with G. r's., 733
- Carbonyl halides (α, β -unsat'd)—reactions with G. r's., 732-733
- Carbonyl reduction by G. r's.:
asymmetric, 154-157
mechanism of, 154, 156
suppression of, 157-158
- Carbonyl sulfide—reactions with G. r's., 1288
- Carboxylic acids from CO₂, 913-948
- Carboxylic acids and their salts:
reactions with G. r's., 948-960
t-alcohol form'n, 948-949
enolization, 949-950
ketone form'n, 948-949
- Carboxylic amides:
as sources of amines, 871-872
as sources of imides, 872-873
as sources of ketones, 870
as sources of nitriles, 870-871
condensations of, 875-876
from nitriles, 774
reactions with G. r's., 870-876
- Carboxylic anhydrides:
as sources of *t*-alcohols, 846-847
as sources of keto acids, 847, 849, 851
as sources of ketones, 846-847, 851
- Carboxylic anhydrides: (*cont'd*)
as sources of phthalides, 848, 851
reactions with G. r's., 846-869
mechanism of, 849-851
- Carboxylic esters (*see* Esters, carboxylic)
- Carbylamines (*see* Isonitriles)
- "Catalyst(s)" in G. r. prep'n:
ethers as, 50, 51
ethyl orthosilicate as, 11
sulfides (organic) as, 51
tertiary amines as, 50-53
tribenzylphosphine oxide as, 51
triethylsulfonium iodide as, 53
- Chemiluminescence of G. r's., 46, 1273-1274
- Chloroform as inhibitor in G. r. prep'n, 13
- Chlorosulfonates—reactions with G. r's., 1295
- Chromenes from lactones, 575-576
- Cinnamyl Grignard reagents:
constitution of, 60, 1147-1148
prep'n of, 28
- Claisen condensations, 564-567
- Classical method of G. r. prep'n, 22-32
limitations of, 32
- Cleavages of:
ethers:
anomalous (by G. r's.), 1036-1040
by carbonyl halides, 727
by G. r. components, 100, 1013-1025
reductive, 128, 1025-1029
"solvolytic," 100, 1025-1026
ethers (allylic), 1025
ethers (cyclic) by G. r's., 1031-1035
ethers (dialkylaminomethyl), 1030
ethers (imino), 1030
"hindered" esters (alkyl), 567-572
"hindered" esters (allylic), 569-572
"hindered" esters (aryl), 572
ketimine condens'n products, 1209
- Cobaltous halides:
reactions induced by, 122-124, 1057-1059, 1063
reactions with G. r's., 121-122, 123
- Cobaltous subhalides (\cdot CoX) in:
acyl radical coupling, 126-127, 164
alkyl radical coupling, 122-124, 1057-1059
functional exchange, 130, 1063
ketone reduction, 127-128
- Color tests for Grignard reagents, 95-98
- Complex formation of:
cuprous halides with olefins, 221
G. r. components with:
t-amines, 142, 156
carbonyl comp'ds, 138-142, 223, 1141

- Complex formation of: (*cont'd*)
 G. r. components with: (*cont'd*)
 ethers, 99-102, 106, 156, 1023
 ketimines, 1209
 nitriles, 142, 767-769
Condensations (acetoacetic ester-type), 564-567
Condensations (Claisen), 564-567
Condensations (cross) of aldehydes and ketones, 178, 180, 242
Condensations of:
 aldehydes and ketones, 176-181
 amides, 875-876
 ketimines, 1208-1209
 nitriles, 774-776
Conjugated carbonyl systems:
 add'n of G. r's. to, 196-238
 1,2-add'n of G. r's. to:
 mechanism of, 223-224
 suppression of, 221
 1,2- and 1,4-add'n of G. r's. to, 196-234
 constitutional factors affecting, 224-228
 effect of cuprous halides on, 219-221
 facilitation of 1,4-add'n, 219-221
 suggested research precautions, 227-228
 T. VI-XVI, 198-218
 1,4-add'n of G. r's. to:
 involving aromatic nuclei, 228-232
 mechanism of, 221-223
 suppression of, 223-224
 1,6-add'n of G. r's. to, 234-238
 involving aromatic nuclei, 236-238
 involving cleavages, 238
 mechanism of, 237-238
Constitutional factors affecting add'n to conj. carbonyl systems, 224-228
Constitution and dissociation of Grignard reagents, 99-115
Constitution of:
 butenyl G. r's., 60, 1156-1157
 cinnamyl G. r's., 60, 1147-1148
 G. r's. from arylacetic acids, 73
 G. r's. from sulfones, 74
 pyrryl G. r's., 75-77
Continuous activation, 38-45 (*see* Entrainment)
Copper-magnesium alloy, 12
 effect on yield of G. r., 12, 13
Coupling of radicals:
 R_2 from 2 RAg, 118
 R_2 from 2 RCN, 778-779
 R_2 from 2 RMgX:
 in Grignard electrolysis, 112
 in metallic halide reactions, 119-122
Coupling of radicals: (*cont'd*)
 R_2 from 2 RX:
 as source of Wurtz product, 63, 64
 in G. r.-aralkyl halide reactions, 1054-1056
 $(RCO)_2$ from 2 RCOX, 126-127, 164, 727-729, 1056
Coupling reactions (uncatalyzed), 131-132
Cross-condens'n of aldehydes and ketones, 178, 180, 242
 α -Cumyl radicals—dimerization of, 124
Cuprous halides:
 complex formation with olefins, 221
 effect on 1,2- and 1,4-add'n, 219-221
 in acetylenic G. r.-alkyl halide condens'n, 1053-1054
 reactions with G. r's., 119, 134-135
Cyanamides—reactions with G. r's., 788, 1260
Cyano compounds—reactions with G. r's., 767-845
Cyano group:
 as pseudohalogen, 776-778
 displacement in Grignard reactions, 776-782
 reactions with G. r's., 785-787
 reductive displacement of, 779-782
Cyanogen halides:
 as halogenating reagents, 787-788
 reaction with G. r's., 787-788
Cyanohydrins—reactions with G. r's., 783-784
Cyclic alcohols from cyclic ketones, 146, 453-528
Cyclic ketones (T. VI-XIX), 453-528
Cyclic reactor, 23

Dealkylation of alkoxy groups, 1029-1030
Decomposition potential in G. r. electrolysis, 114
Demethoxylation of aromatic ketones and nitriles, 238, 1036-1040
Demethylation of methoxy groups, 1029-1030
Detection of Grignard reagents, 95-98
 Gilman's Color Test I, 95-97
 Gilman's Color Test II, 97
 Gilman's Color Test III, 97-98
 Michler's ketone color test, 95-97
Determination of Grignard reagents, 92-95
 acid-titration, 94-95
 gas-analysis, 94
 iodimetric, 92-94
Diazo compounds—reactions with G. r's., 1223-1226

- Diazomethane—configuration of, 1225
N,N-Diethylphthalamic acid as source of phthalides, 873
 Dihalides (alkyl)—dehalogenation by G. r's., 1053
 Dihalides (*gem*) in G. r. prep'n, 32
 Dihalides (non-*vicinal*) in G. r. prep'n, 34
 Dihalides (*vic*) in G. r. prep'n, 33
 Dimerization of radicals:
 acyl, 126-127
 as source of Wurtz product, 63, 64
 α -cumyl, 124
 induced by metallic halides, 118, 124-125, 1056-1059
 in G. r. electrolyses, 112
 in Grignardization, 63, 64
 in Grignard systems, 116
 ketyl, 127-128
 Diorganomagnesium compounds:
 as G. r. components, 102
 in Schlenk equilibrium, 104
 discovery of, 1
 preparation of:
 by dioxane pptn. method, 106-107
 by reaction of Mg with RI, 1-2
 by reaction of Mg with R_2SO_4 , 90-91
 reactions with ethylene oxide, 963
 Dioxane as precipitant for MgX_2 and $RMgX$, 105-107
 Direction of ring-opening of epoxides—factors influencing, 967-975
 in additions, 973-975
 in isomerizations, 968-973
 Disproportionation:
 in ether cleavages, 1015, 1023, 1025
 of Grignard reagents, 102, 104-109
 of radicals:
 induced by metallic halides, 124-125
 in G. r. electrolyses, 112
 in Grignardization, 6, 59, 63, 64
 in Grignard systems, 116, 118
 of $RMgOSO_2R$, 91
 Dissociation of Grignard reagents:
 homolytic, 114-115, 116-117
 ionic, 112
 Disulfoxides (*see* Thiolsulfonates)
 Dithiocarboxylic acids from carbon disulfide, 1286-1287
 Electrolysis of G. r. sol'ns, 109-110, 112-114
 Electrolytic discharge of (G. r.) ions, 112-114
 Electrolytic magnesium, 8
 Electrolytic properties of G. r. sol'ns, 109-114
 Electronegativities (relative) of organic radicals, 20, 113, 124, 153, 225, 227
 Enaminization of ketimines, 1208
 Enolate formation by G. r's., 166-176
 mechanism of, 174-176
 Enolate ions as resonance hybrids, 194
 Enolates:
 analogy with sulfone G. r's., 1297-1299
 as products of 1,4-addition, 193, 197, 222
 as products of G. r.-carbonyl halide reactions, 729-730
 as products of G. r.-ketene reactions, 238-239
 as products of G. r.-ketone reactions, 166-176, 193
 as products of reductive enoliz'n, 189-196
 as quasi G. r's., 73, 180, 194, 348, 729
 stereoisomerism of, 193-194, 222
 Enol content of ketones (estimated) by:
 C_2H_5ZnI reaction (T. VI-XII), 172
 Meyer's Br method (T. VI-XIII), 173
 Schwarzenbach's Br method (T. VI-XIV), 173
 Enolizable ketones as active H comp'ds, 166-167
 Enolization of:
 camphor—effect of G. r. and solvent on rate of (T. VI-V), 168
 camphor by CH_3MgI —rate of (T. VI-IV), 167
 carboxylates, 949-950
 ketones by G. r's., 166-176
 mechanism of, 174-176
 pulegone by non-reducing G. r's. (T. VI-VI), 168
 Enolization (reductive) of:
 α -halo carboxylates, 950
 α -halo ketones, 189-196
 mechanism of, 193-196
 "Enol peroxides," 192
 Entrainment method of G. r. prep'n, 38-45
 Epoxide isomerization, 965-967, 968-973
 analogy with hydrobenzoin rearrangement, 968 *ff.*
 Epoxides as intermediates in halo-hydrate rearrangements, 189
 Epoxides (unsat'd)—reactions with G. r's., 975-976
 Equilibrium:
 disproportionation of G. r's., 102, 104-109
 homolytic dissociation of G. r's., 114
 Schlenk, 68, 104-109

- Ester formation through ether cleavage, 727
- Esters (carbonic)—reaction with G. r's., 560-561, 580-581
- Esters (carboxylic):
as inhibitors in G. r. prep'n, 13
cleavages of "hindered," 567-572
preparation of from:
carbonates, 560, 580-581
chloroformates, 560, 579
reactions with G. r's., 549-560, 561-573, 579, 581-585, 591-594, 595-674
ketone (or aldehyde) form'n, 561-562
"normal" addition, 549-561
reduction, 562-563
relative reactivities of, 554-557
- Esters (chloroformic)—reactions with G. r's., 560, 579, 733, 738, 739-740
- Esters (ortho)—prep'n from orthocarbonates, 561, 581
- Esters (orthocarbonic)—reactions with G. r's., 561, 581
- Esters (orthoformic)—reactions with G. r's., 561, 586-591
- Esters (silicon)—reactions with G. r's., 1307, 1322-1331
- Esters (sulfonic)—reactions with G. r's., 1278, 1281-1285
- Esters (sulfuric)—reactions with G. r's., 1277-1278, 1278-1281
- Estimation and detection of G. r's., 92-98
- Ethanols from ethylene oxide, 976-977, 978-987
- Ether—quantity in G. r. prep'n, 16
- Ether cleavage:
by carbonyl halides, 727
by Grignard reagents, 100, 1013-1025
reductive, 128, 1025-1029
"solvolytic," 100, 1025-1026
- Ether cleavage (anomalous) by G. r's., 1036-1040
- Etherates of Grignard reagents, 99-102
- Ethers:
as "catalysts" in G. r. prep'n, 50, 51
complexes with G. r's., 99-102, 156
prep'n from acetals, 1041-1045
reactions with G. r's., 1013-1041
cleavage (heterolytic), 1013-1025
cleavage (reductive), 128, 1025-1030
cleavages (anomalous), 1036-1040
cleavage ("solvolytic"), 100, 1025-1026
G. r. form'n from, 74, 1040-1041
- Ethers (allylic)—reactions with G. r's., 1025
- Ethers (aromatic) as sources of G. r's., 74, 1040-1041
- Ethers (cyclic)—reactions with G. r's., 1031-1035
- Ethers (dialkylaminomethyl)—reactions with G. r's., 1030
- Ethers (halo) in G. r. prep'n, 35
- Ethers (ω -haloalkyl phenyl)—reactions with $\cdot\text{CoX}$, 128-129
- Ethers (imino)—reactions with G. r's., 1030
- Ethers (other than Et_2O) in G. r. prep'n, 45, 1166, 1167
- Ethers (thio and seleno)—reactions with G. r's., 1035-1036
- Ethyl acetate as inhibitor in G. r. prep'n, 13
- Ethyl bromide as activator in G. r. prep'n, 10
- Ethyl iodide as activator in G. r. prep'n, 11
- Ethyl orthosilicate as activator in G. r. prep'n, 11
- Ethylene oxide as source of ethanols, 976-977, 978-987
- Ethylmagnesium bromide as activator in G. r. prep'n, 10, 11
- Excess halide as solvent in G. r. prep'n, 53-56
- Exchange (functional), 40, 129, 130, 1060-1064
as free-radical reaction, 44
- Ferric chloride:
in functional exchange, 1064
reactions with G. r's., 120-121, 135-136
- Ferrocene, 120
- Fluorides in G. r. prep'n, 38
- Forced reactions:
of alkyl halides, 1059-60
of phenyl isocyanate, 1200
- Formamides (*N,N*-disubstituted) as sources of aldehydes, 870
- Free radicals:
as sources of G. r's., 86-87
attack of on solvents, 124, 151
in metallic halide reactions, 124
behavior of in solution, 124-126
dimerization of, 124-125, 126-127, 127-128, 151
acyl, 126-127
 α -cumyl, 124
ketyl, 127-128
disproportionation of, 124-125, 151
in functional exchange, 44

Free radicals: (*cont'd*)

- in reductive ether cleavage, 1025-1029
- reaction with hydrogen donors, 124
- rearrangement of, 124-125
- Functional exchange, 40, 129, 130, 1060-1064
 - as free-radical reaction, 44
- Furoxans—reactions with G. r's., 1232-1233

Gas-analysis estimation of G. r's., 94

Gilman's Color Test I (Michler's ketone), 14, 76, 95-97

Gilman's Color Test II, 97

Gilman's Color Test III, 97-98

Glycols (tetramethylene) from lactone reactions, 574-575

"Glyoxime peroxides" (*see* Furoxans)

Grignard machine, 168, 170-172, 1169

Grignard reagent components—assoc'n with:

- t*-amines, 142, 156
- carbonyl comp'ds, 138-142, 223, 1141
- each other, 102-104
- ethers, 99-102, 106, 156, 1023
- nitriles, 142, 767-769

Grignard reagent formation:

- as radical process, 60
- mechanism and kinetics of, 56-66
- solvent involvement in, 63

Grignard reagent red'n of CO groups:

- asymmetric, 154-157
- mechanism of, 154, 156
- suppression of, 157-158

Grignard reagents:

- acetylenic, 66-70
 - condens'n with alkyl halides, 1053-1054
- 1,2-add'n to conj. carbonyl systems:
 - mechanism of, 223-224
 - suppression of, 221
- 1,2- and 1,4-add'n to conj. carbonyl systems, 196-234
 - constitutional factors affecting, 224-228
- 1,2- and 1,4-add'n to conj. carbonyl systems, (*cont'd*)
 - effect of cuprous halides on, 219-221
 - facilitation of 1,4-add'n, 219-221
 - suggested research precautions, 227-228
- T. VI-XVI, 198-218
- 1,4-add'n to conj. carbonyl systems:
 - involving aromatic nuclei, 228-232
 - mechanism of, 221-223
 - suppression of, 223-224

Grignard reagents: (*cont'd*)

1,4-add'n to unsat'd carboxylic esters, 563-564

1,4-add'n to unsat'd epoxides, 975-976

1,4-add'n to unsat'd nitriles, 782-783

1,6-add'n to conj. carbonyl systems, 234-238

involving aromatic nuclei, 236-238

involving cleavages, 238

mechanism of, 237-238

allylic:

"abnormal" reactions of, 1145-1157

constitution of, 60

prep'n of, 17, 18, 24, 27, 28, 47-48 (and components) as Lewis acids, 111, 174-176, 964-965, 967

(apparent) mol. wts. of in sol'n, 102-103

assoc'n of components with:

- t*-amines, 142, 156
- carbonyl comp'ds, 138-142, 223, 1141
- each other, 102-104
- ethers, 99-102, 106, 156, 1023
- nitriles, 142, 767-769

asymmetric as asym. reducing agents, 154-157

butenyl:

constitution of, 60, 1158

prep'n of, 24, 47-48

carbazolyl, 86

chemiluminescence of 46, 1273-1274

cinnamyl:

constitution of, 60

prep'n of, 28

cleavage of ethers by, 100, 1013-1025

complex formation of with:

- t*-amines, 142, 156
- carbonyl comp'ds, 138-142, 223, 1141
- ethers, 99-102, 106, 156, 1023
- ketimines, 1209
- nitriles, 142, 767-769

constitution and dissoc'n of, 99-115

detection of, 95-98

Gilman's Color Test I, 95-97

Gilman's Color Test II, 97

Gilman's Color Test III, 97-98

Michler's ketone color test, 95-97

discovery of, 4

disproportionation of, 102, 104-109

dissociation of,

homolytic, 114-115, 116-117

ionic, 112

Grignard reagents: (*cont'd*)

- electrolysis of, 109-110, 112-114
 - attack on solvent in, 112
 - decomposition potential in, 114
 - radical dimerization in, 112
 - radical disproportionation in, 112
 - enolates as quasi, 73, 180, 194
 - enolization of ketones by, 166-176
 - mechanism of, 174-176
 - enoliz'n (reductive) of α -halo ketones by, 189-196
 - mechanism of, 193-196
 - estimation of, 92-95
 - acid-titration, 94-95
 - gas-analysis, 94
 - iodimetric, 92-94
 - etherates of, 99-102
 - imidazolyl, 84-85
 - index of, 1347-1362
 - indolyl, 80-84
 - ionization of, 110-112
 - ketoization and aldolization by, 176-181
 - mechanism of, 179
 - luminescence of, 46, 1273-1274
 - molecular weights of in sol'n, 102-103
 - pyrazolyl, 85-86
 - pyrryl, 75-80
 - constitution of, 75-77
 - (quasi) enolates as, 73, 180, 194
 - (quasi) from arylacetic acids, 72
 - (quasi) from sulfones, 73
 - radical reactions of, 116-137
 - reduction of aldehydes and ketones by, 147-157
 - reductive enoliz'n of α -halo ketones by, 189-196
 - mechanism of, 193-196
 - relative reducing tendencies of, 153
 - Schlenk equilibrium of components of, 68, 104-109
- Grignard reagents—prep'n of, 4, 5-91
- activators and inhibitors in, 8-15
 - agitation of reaction mixture in, 19
 - apparatus for (classical), 22
 - apparatus for (cyclic reactor), 23
 - apparatus for (mech. activation), 7
 - by classical methods, 22-32
 - by entrainment, 38-45
 - by Grignardization of halides, 5-56
 - by hydrogen displacement, 66-86
 - by olefin add'n of RMgX , 87-90
 - copper-magnesium alloy in, 12
 - from acetylenic hydrocarbons, 66-70
 - from alkyl sulfates, 90-91
 - from allylic halides, 17, 18, 24, 27, 28, 47-48
 - from aromatic ethers, 74, 1040-1041

Grignard reagents—prep'n of, (*cont'd*)

- from butenyl halides, 24, 47-48
 - from carbazole, 86
 - from dihalides (*gem*), 32
 - from dihalides (non-vicinal), 34
 - from dihalides (*vic*), 33
 - from ethers, 74, 1040-1041
 - from fluorides, 38
 - from free radicals, 86-87
 - from imidazole, 84-85
 - from 2-methylbenzothiazoles, 74
 - from nitrogen heterocycles, 75-86
 - from non-acetylenic hydrocarbons, 71-75
 - from olefins, 87-90
 - from organolithium comp'ds, 90
 - from organomercuri comp'ds, 90
 - from pyrazole, 85-86
 - from pyrroles, 75-80
 - from thiophene, 75
 - from vinyl halides, 37
 - general method for, 25
 - halides for, 25
 - in ethers other than Et_2O , 45, 1166, 1167
 - in halide (excess) as solvent, 53-56
 - inhibitors in, 13-15
 - in hydrocarbons, 50-53
 - in solvents other than Et_2O , 45-52
 - in tertiary amines, 49
 - iodine-activated Mg alloy in, 12
 - iodine-activated Mg in, 8
 - limitations of classical methods, 32
 - quality of Mg in, 6, 24
 - quantity of Et_2O in, 16
 - (quasi) from arylacetic acids, 72
 - (quasi) from sulfones, 73
 - rate of halide add'n in, 18
 - reagents for, 24
 - relative reactivities of halides in, 20
- Grignard reagents—reactions with:
- acetals and ketals, 1041-1045
 - acetylenic hydrocarbons, 66-70
 - active H comp'ds, 66-86
 - aldazines, 1211-1212
 - aldehydes and ketones, 138-238
 - "normal" addition, 138-142
 - reduction, 147-157
 - aldimines, 1204-1208
 - alkoxyamines, 1236-1237
 - alkyl halides, 1046-1132
 - coupling, 1054-1056
 - coupling (induced), 1056-1059
 - dehalogenation, 1053
 - dehydrohalogenation, 1052-1053
 - halohydrins, 1064-1066
 - mechanism of, 1048-1053
 - "normal" condens'n, 1046-1052

Grignard reagents—reactions with:
 (*cont'd*)
 alkyl sulfates, 1277-1278, 1279-1281
 amides, 870-876
 amide condens'ns, 875-876
 amine form'n, 871-872
 imide form'n, 872-873
 ketone form'n, 870
 nitrile form'n, 870-871
 amides (α -halo), 873-875
 amino alcohol form'n, 874
 reductive dehalogen'n, 873-874
 amides (α, β -unsat'd), 875
 amine oxides, 1233-1235
 ammonia, amines, etc., 1255-1259
 azides, 1226-1227
 azo comp'ds, 117, 1249-1251
 azoxy comp'ds, 1232
 carbazole, 86
 carbodiimides, 1213
 carbon disulfide, 1286-1288
 carbonyl halides, 709-766
 "abnormal," 730-731
 carbonyl halides (α -halo), 731-732
 carbonyl halides (α, β -unsat'd), 732-733
 carbonyl sulfide, 1288
 carboxylates, 948-960
 t-alcohol form'n, 948-949
 enolization, 949-950
 ketone form'n, 948-949
 carboxylic anhydrides, 846-869
 t-alcohol form'n, 846-847
 keto acid form'n, 847, 849, 851
 ketone form'n, 846-847, 851
 mechanism of, 849-851
 phthalide form'n, 848, 851
 chlorosulfonates, 1295
 cobaltous halides, 121-122, 123, 136
 conjugated carbonyl systems, 196-238
 cuprous halides, 119, 134-135
 cyanamides, 788, 1260
 cyano compounds, 767-845
 cyanogen, 785-787
 cyanogen halides, 787-788
 cyanohydrins, 783-784
 diazo comp'ds, 1223-1226
N,N-diethylphthalamic acid, 873
 epoxides, 961-1012
 epoxide isomerization, 965-967, 968-973
 esters (carbonic), 560-561, 580-581
 esters (carboxylic), 549-560, 561-573, 579, 581-585, 591-594, 595-674

Grignard reagents—reactions with:
 (*cont'd*)
 esters (chloroformic), 560, 579
 esters (orthocarbonic), 561, 581
 esters (orthoformic), 561, 586-591
 ethers, 1013-1041
 cleavage (heterolytic), 1013-1025
 cleavage (reductive), 128, 1025-1030
 cleavage ("solvolytic"), 100, 1025-1026
 cleavages (anomalous), 1036-1040
 Grignard reagent formation, 74, 1040-1041
 ethers (cyclic), 1031-1035
 ethers (thio and seleno), 1035-1036
 ethylene oxide, 961-965, 976-977, 978-987
 ferric chloride, 120-121, 135-136
 formamides, 870
 furoxans, 1232-1233
 Group IB halides, 118-119, 133-135
 Group VIII halides, 117-122, 135-136
N-halo amines and imines, 1243-1248
 α -halo ketones and aldehydes, 181-196
 addition ("normal"), 182
 enolization, 181, 195-196
 halogen replacement, 182-189
 reductive enoliz'n, 189-196
 hydramides, 1212-1213
 hydrocarbons:
 acetylenic, 66-70
 non-acetylenic, 71-75
 olefinic, 87-90
 hydroxylamines, 1235-1237
 imidazole, 84-85
 imides, 876-878
 indoles, 80-84
 iodine, 92-93
 isocyanates, 1199-1204
 forced reactions, 1200
 isonitriles, 1260
 isonitroso comp'ds, 1221-1222
 isothiocyanates, 1199-1204
 ketenes, 238-239
 ketimines, 1208-1211
 addition ("normal"), 1210-1211
 1,4-addition, 1209-1210
 condensation, 1208-1209
 enaminization, 1208
 ketones and aldehydes, 138-238
 "normal" addition, 138-142
 reduction, 147-157
 lactams, 878-879
 lactones, 574-578
 metallic halides, 117-122, 133-136

Grignard reagents—reactions with:
 (*cont'd*)
 nickel chloride (NiCl_2), 121, 136
 nitrates (organic), 1243
 nitrile oxides, 1235
 nitriles, 767-785, 792-845
 t-alcohol form'n, 772-773
 t-alkylamine form'n, 772-773
 amide form'n, 774
 condens'n and polymeriz'n, 774-776
 coupling, 778-779
 cyano group displacement, 776-782
 keteniminate form'n, 773-776
 ketimine form'n, 767-772
 ketone form'n, 767-772
 mechanism of, 767-769
 reductive displacement of CN, 779-782
 nitriles (α -halo), 784-785
 nitriles (α, β -unsat'd), 782-783
 nitrites (organic), 1242-1243
 nitro comp'ds, 1237-1242
 nitrogen comp'ds (unclassified), 1260-1263
 nitrogen heterocycles, 75-86
 nitroso comp'ds, 1228-1229
N-nitrosoamines, 1229-1232
 non-acetylenic hydrocarbons, 71-75
 olefins, 87-90
 osazones, 1216-1217
 oxides and halo oxides of N, 1243
 oxides of carbon, 909-948
 carbon dioxide, 913-948
 carbon monoxide, 910-913
 carbon suboxide, 909
 oximes, 1217-1221
 oxygen, 1264-1274
 phenylhydrazones, 1213-1216
 phosgene, 733, 734-735
 phosphorus comp'ds, 1335, 1337-1345
 phosphoric and phosphorous esters, 1339
 phosphorus sulfides, 1340
 pyrazole, 85-86
 pyrroles, 75-78
 quaternary salts, 1251-1255
 quinones, 529-548
 selenium, 1276
 selenium comp'ds, 1302-1303
 semicarbazones, 1222-1223
 silicon comp'ds, 1306-1331
 silicon esters, 1307, 1322-1331
 silicon halides, 1306-1307, 1310-1331
 silver halides, 118-119, 133-134
 sulfenates, 1285

Grignard reagents—reactions with:
 (*cont'd*)
 sulfinates, 1285
 sulfites, 1285
 sulfones, 73, 1297-1299
 sulfonic esters, 1278, 1281-1285
 sulfonyl halides, 1290-1294
 sulfoxides, 1296-1297
 sulfur, 1274-1276
 sulfur chlorides, 1295
 sulfur comp'ds (unclassified), 1300-1302
 sulfur dioxide, 1288-1290
 sulfonyl chloride, 1294-1295
 tellurium, 1276
 tellurium comp'ds, 1303-1305
 thiocarboxylates, 1286
 thioketones (thiones), 1299
 thiol-sulfonates, 1286
 thionyl chloride, 1294
 Grignard reagents—yields of:
 effect of Cu-Mg alloy, 13
 effect of Et_2O -dil'n of halide, 17
 effect of halide-add'n rate, 19
 effect of halide halogen, 32
 prepared in benzene, 52
 prepared in *n*- Bu_2O , 47
 prepared in classical manner, 30
 prepared in hydrocarbons, 53
 prepared in 4-methyl-1,3-dioxane, 49
 Grignardization of organic halides:
 as method of G. r. prep'n, 5-56
 as radical process, 60
 dimerization of radicals in, 63
 mechanism and kinetics of, 56-66
 solvent involvement in, 63
 Grignard-type reagents from alkyl sulfates, 90-91
 Group IB halides:
 reactions with G. r's., 118-119, 133-135
 Group VIII (Fe, Co, Ni) halides:
 reactions with G. r's., 119-122, 135-136
 Halide add'n rate in G. r. prep'n, 18-19
 Halide dil'n in G. r. prep'n, 16-17
 Halide (excess) as solvent in G. r. prep'n, 53-56
 Halide reactivities (relative) in G. r. prep'n, 20
 Halides (alkyl):
 reactions with G. r's., 1046-1132
 dehydrohalogen'n, 1052-1053
 mechanisms of, 1048-1053
 "normal" condensation, 1046-1052

- Halides (allylic):
 reaction with G. r's., 1050-1051, 1157-1158
- Halides (carbonyl):
 "abnormal" reactions of, 730-731
 coupling reactions of, 126-127, 164, 727-729
 reactions of α -halo with G. r's., 731-732
 reactions of α, β -unsat'd with G. r's., 732-733
 ether cleavage by, 727
 reactions with G. r's., 709-766
 reduction by G. r's., 725-727
- Halides (carbonyl)—other than RCOX:
 reactions with G. r's., 733
- Halides for prep'n of G. r's., 25
- Halides (silicon):
 reactions with G. r's., 1306-1307, 1310-1331
- Halides (vinyl) in G. r. prep'n, 37
- Halo ethers in G. r. prep'n, 35
- α -Halo ketones and aldehydes—reactions with G. r's., 181-196
 enolization, 181, 195-196
 halogen replacement, 182-189
 "normal" addition, 182
 reductive enolization, 189-196
- α -Halo sulfones—reactions with G. r's., 1298
- ω -Haloalkyl phenyl ethers—reaction with cobaltous subhalides, 128-129
- N-Haloamines and N-haloimines—reaction with G. r's., 1243-1248
- Halogen ("positive") in reductive enoliz'n, 195
- Halohydrate rearrangements:
 epoxide-intermediate, 189
 pinacol-pinacolone type, 183-188
- Halohydrins from α -halo ketones, 182
- Halohydrins—reactions with G. r's., 1064-1066
- Halomercuri comp'ds as sources of G. r's., 90
- Heterocycles (nitrogen) as sources of G. r's., 75-86
- Hexaarylethane form'n, 729
- Hexestrol dimethyl ether prep'n, 1057-1058
- "Hindered" esters (alkyl)—cleavage by G. r's., 567-572
- "Hindered" esters (allylic)—cleavage by G. r's., 569-572
- "Hindered" esters (aryl)—cleavage by G. r's., 572
- Homolytic dissoc'n of G. r's., 114-117
- Hydramides—reaction with G. r's., 1212-1213
- Hydrazo comp'ds from azo comp'ds, 1249-1251
- Hydrazones from diazo comp'ds, 1223-1226
- Hydrobenzoin-type rearrangements of epoxides, 968-973
- Hydrocarbons (acetylenic) as sources of G. r's., 66-70
- Hydrocarbons as solvents in G. r. prep'n, 50
- Hydrocarbons (non-acetylenic) as sources of G. r's., 71-75
- Hydrogen ("active"):
 groups containing, 1169-1171
 Zerewitinoff det'n of, 1166-1198
- Hydrogen chloride as inhibitor in G. r. prep'n, 14
- Hydrogen displacement methods of G. r. prep'n, 66-86
- Hydroperoxides by G. r. oxid'n, 1266-1267
- Hydroxylamines and alkoxyamines—reactions with G. r's., 1235-1237
- Hydroxylamines from nitroso comp'ds, 1228
- Imidazole as source of G. r's., 84-85
- Imides from amides, 872-873
- Imides—reactions with G. r's., 876-878
- Indenones from phthalides, 577-578
- Indolyl Grignard reagents, 80-84
- Induced homolytic dissoc'n of G. r's., 116-117
- Inhibitors (activators and) in G. r. prep'n, 8, 13
- Internal Wurtz reaction, 33
- Inversion (Walden) in:
 allylic halide reactions, 1050-1051
 epoxide rearrangements, 972
 ether cleavage, 1024
 sulfonic ester reactions, 1278
- Iodimetric estimation of G. r's., 92-95
- Iodine:
 as activator in G. r. prep'n, 8
 as reagent for G. r. estimation, 92-95
 in coupling of alkyl halides, 1057
 reaction with G. r's., 92-93
- Iodine-activated magnesium, 8-9
 Baeyer's, 8
 Gilman's, 9
- Iodine-activated magnesium alloy, 12

- Ionic dissoc'n of G. r's., 110-112
 Ionic species in G. r. sol'ns, 111
 Ions (resonance of):
 benzyl, 1141
 butenyl, 1156, 1157
 phenolate, 1140-1141
 pyrryl, 76-77
 Isobornylmagnesium chloride as asym-
 metric reducing agent, 154-155
 Isobenzofurans from phthalides, 577
 Isocyanate (phenyl) as source of:
 anilides, 1199-1204
 anilines (*N,N*-disubstituted), 1200
 Isocyanates—reaction with G. r's.,
 1199-1204
 Isomerization of epoxides by metallic
 halides, 965-967, 968-973
 analogy with hydrobenzoin rearrange-
 ment, 968ff
 Isonitriles—reactions with G. r's.,
 1260
 Isonitroso comp'ds—reactions with G.
 r's., 1217-1222
 Isothiocyanates—reactions with G.
 r's., 1199-1204
- Ketals (acetals and)—reactions with
 G. r's., 1041-1045
 Ketenes—reactions with G. r's., 238-
 239
 Ketenimines from nitriles, 773-774
 Ketimines:
 as active H comp'ds, 1208
 prep'n from nitriles, 767, 770-771
 reactions with G. r's., 1208-1211
 addition ("normal"), 1210-1211
 1,4-addition, 1209-1210
 condensation, 1208-1209
 enamination, 1208
 Keto acids from carboxylic anhydrides,
 847, 849, 851
 Ketoanils (*see* Ketimines)
 Ketolization and aldolization, 176-181
 mechanism of, 179
 Ketone (Michler's) as color-test re-
 agent, 14, 76, 95-97
 Ketones:
 enolization of by G. r's., 166-176
 mechanism of, 174-176
 estimated enol content of:
 by C_2H_5ZnI reaction (T. VI-XII),
 172
 by Meyer's Br method (T. VI-XIII),
 173
 by Schwarzenbach's Br method (T.
 VI-XIV), 173
 from amides, 870
- Ketones: (*cont'd*)
 from carbon dioxide, 913-914, 917,
 918, 919, 920
 from carbonyl halides, 712-724
 from carboxylic anhydrides, 846-
 847, 851
 from carboxylic esters, 561-562
 from cyanogen, 785-786
 from nitriles, 767, 769-772
 reduction of by:
 alkoxides, 158-160
 Grignard reagents, 147-157
 metallic subhalides, 127-128,
 160-166
 relative reactivities of G. r's., to-
 ward, 140, 142, 227
 relative reactivities toward G. r's.,
 225, 1174
 Ketones (acyclic)—reactions with G.
 r's. (T. VI-XVIII), 310-452
 Ketones and aldehydes:
 alkoxide red'n of, 158-160, 164
 complex form'n with G. r's., 138-142
 cross-condens'n of, 178
 Grignard red'n of, 147-166
 magnesium halide red'n of, 160-166
 Meerwein red'n of, 158-160, 164
 reactions with G. r's., 138-238
 "normal" addition, 138-142
 reduction, 147-157
 Ketones and aldehydes (α -halo):
 reactions with G. r's., 181-196
 enolization, 181, 195-196
 halogen replacement, 182-189
 "normal" addition, 182
 reductive enolization, 189-196
 Ketones and esters as inhibitors in G.
 r. prep'n, 13
 Ketones (cyclic)—reactions with G.
 r's., (T. VI-XIX), 453-528
 Ketones (enolizable) as active H
 comp'ds, 166-167
 Ketones (sym.) from esters, 566-567
 Ketones (unsym.)—asym. red'n of,
 154-157, 160
 Ketyl radicals—dimerization of, 127-
 128
 Kinetics and mechanism of G. r. form'n,
 56-66
- Lactams—reactions with G. r's., 878-
 879
 Lactones—reactions with G. r's., 574-
 578
 Lewis acids:
 G. r. sol'n components as, 111, 174,
 964-965, 967

Lewis acids: (*cont'd*)

- in cleavage of oxirane ring, 964-965
- in G. r. enoliz'n of ketones, 174-176
- in G. r. isomeriz'n of epoxides, 967

Limitations of classical method of G. r. prep'n, 32

Lithium comp'ds as sources of G. r's., 90

Luminescence (O_2 -induced) of G. r's., 146, 1273-1274

Machine (Grignard), 168, 170-172, 1169

Magnesious halides:

- as activators in G. r. prep'ns, 9
- as reductants:
 - of carbonyl comp'ds, 160-166
 - of nitroso compounds, 1228
 - of quinone add'n products, 531-532
 - of quinones, 532-533
 - of thioketones (thiones), 1199
- combin'n with free radicals, 86-87
- in coupling of aralkyl halides, 1056-1057

Magnesium:

- activation of:
 - continuous, 38-45
 - electrolytic, 8
 - mechanical, 7
- electrolytically deposited, 8
- iodine-activated, 8-9
 - Baeyer's, 8
 - Gilman's, 9
- mechanically-activated, 7
- quality of in G. r. prep'n, 6, 24

Magnesium alloys, 12

Magnesium bromide:

- as activator in G. r. prep'n, 10
- as suppressor of G. r.-carbonyl red'n, 157-158
- preparation of ethereal, 33
- sol'y in Et_2O and G. r. sol'ns, 44

Magnesium chloride—precipit'n from $RMgCl$ sol'ns, 108

Magnesium-copper alloy, 12-13

Magnesium halides:

- as G. r. components, 102
- in epoxide isomerization, 965-967
- in Schlenk equilibrium, 104

Magnesium iodide:

- as activator in G. r. prep'n, 9
- as source of $\cdot MgI$, 165

Mechanically-activated magnesium, 7

Mechanism:

- of 1,2-add'n to conj. carbonyl systems, 223-224

Mechanism: (*cont'd*)

- of 1,4-add'n to conj. carbonyl systems, 221-223
 - of 1,6-add'n to conj. carbonyl systems, 237-238
 - of aldolization and ketolization, 179
 - of alkoxide-carbonyl reduction, 160
 - of allylic ether cleavage, 1025
 - of disprop'n in ether cleavage, 1025
 - of enolate form'n by G. r's., 174-176
 - of ether cleavage (heterolytic), 1022-1025
 - of G. r.-alkyl halide reactions, 1048-1053
 - dehalogenation, 1053
 - dehydrohalogenation, 1052-1053
 - "normal" condensation, 1048-1052
 - with allylic reactants, 1050-1051
 - of G. r.-carbonyl add'n, 142
 - of G. r.-carbonyl halide reaction, 709-712
 - of G. r.-carbonyl red'n, 154, 156
 - of G. r.-carboxylic anhydride reactions, 849-851
 - of G. r.-carboxylic ester reactions, 553-554
 - of Grignardization, 56-66
 - of G. r.-nitrile add'n, 142, 767-769
 - of ketolization and aldolization, 179
 - of *ortho* condens'ns of benzyl G. r's., 1142-1145
 - of reductive enoliz'n of α -halo ketones, 193-196
- Meerwein reduction of aldehydes and ketones, 158-160, 164
- asymmetric, 160
- Mercuri comp'ds as sources of G. r's., 90
- Metallic halides:
- as activators in G. r. prep'ns, 11
 - in coupling of aralkyl halides, 1056-1059
 - in epoxide isomeriz'n, 965-967
 - in functional exchange, 1060-1064
 - in G. r. enoliz'n of ketones, 176
 - in ketone-pinacol red'n, 166
 - reactions with G. r's., 117-122, 133-136
- Metallic subhalides as ketone reductants, 127-128, 160-166
- Methyl iodide as activator in G. r. prep'n, 11
- 2-Methylbenzothiazoles as sources of G. r's., 74
- (+)-2-Methylbutylmagnesium chloride as asym. reductant, 155
- 4-Methyl-1,3-dioxane as solvent in G. r. prep'n, 49

- Methylene iodide as activator in G. r. prep'n, 11
- Michler's ketone color test, 14, 76, 95-97
sensitivity of, 96-97
- Migratory aptitudes (relative) of groups, 970-972
- Molecular wts. of G. r's. in sol'n, 102-103
- Morpholines (*N*-alkyl) as solvents in G. r. prep'n, 50
- Nickel chloride (NiCl_2)—reactions with G. r's., 121, 136
- Nitrile oxides—reactions with G. r's., 1235
- Nitriles:
complex form'n with G. r's., 142, 767-769
from G. r.-amide reactions, 870-871
from G. r.-cyanogen halide reactions, 787-788
from G. r.-cyanogen reactions, 786
reactions with G. r's., 767-785, 792-845
relative reactivities of G. r's. toward, 142, 768
relative reactivities toward G. r's., 142, 767-768
- Nitriles (α -halo)—reactions with G. r's., 784-785
- Nitriles (α, β -unsaturated)—reactions with G. r's., 782-783
- Nitrites and nitrates (organic)—reactions with G. r's., 1242-1243
- Nitro comp'ds—reactions with G. r's., 1237-1242
- Nitrogen heterocycles as sources of G. r's., 75-86
- Nitroso comp'ds—reactions with G. r's., 1228-1229
- N*-Nitrosoamines—reactions with G. r's., 1229-1232
- Olefins:
as sources of G. r's., 87-90
complex form'n with CuX , 221
- Organocadmium comp'ds in ketone prep'n, 713-724
- Organocopper comp'ds, 119
- Organolithium comp'ds as sources of G. r's., 90
- Organomercuri comp'ds as sources of G. r's., 90
- Organometallic comp'ds (unstable intermediate), 118-119
- Organosilver comp'ds, 118-119
- Organozinc halides in ketone prep'n, 713-724
- Osazones—reactions with G. r's., 1213-1217
- Oxides of carbon—reactions with G. r's., 909-948
carbon dioxide, 913-948
carbon monoxide, 910-913
carbon suboxide, 909
- Oxides of N—reactions with G. r's., 1243
- Oximes and isonitroso comp'ds:
as active H comp'ds, 1217
reactions with G. r's., 1217-1222
- Oxonium comp'ds (supposed) of $\text{Et}_2\text{O-RMgX}$, 99-100
- Oxygen:
as inhibitor in G. r. prep'n, 14
reactions with G. r's., 1264-1274
- Oxygen-induced luminescence of G. r's., 46, 1273-1274
- Phenetole as inhibitor in G. r. prep'n, 13
- Phenols' by oxid'n of G. r's., 1264-1273
- Phenoxy group as pseudohalogen, 35, 1013
- Phenylacetic acids as sources of G. r's. (quasi), 72
- Phenylhydrazones—reactions with G. r's., 1213-1217
- Phenyl isocyanate:
as source of anilides, 1199-1204
as source of anilines (*N,N*-disubstituted), 1200
- Phosgene—reactions with G. r's., 733, 734-735
- Phthalanols from phthalide reactions, 576-577
- Phthalide from *N,N*-diethylphthalamic acid, 873
- Phthalides from carboxylic anhydrides, 848, 851
- Pinacolin, asym. red'n of, 155
- Pinacol rearr's of halohydrates, 183-188
- Pinacols from ketones, 160-166
- "Positive" halogen in reductive enoliz'n, 195
- Potential (decomp.) in G. r. electrolysis, 114
- Precipitation:
of MgX_2 and RMgX components of G. r's.:
by dioxane, 105-107
by pyridine, 106
(spontaneous) of MgCl_2 from RMgCl sol'n's, 108

Preparation of:

- acetals from orthoformates, 561, 586-591
- acids (carboxylic) from CO_2 , 913-948
- acids (dithiocarboxylic) from CS_2 , 1286-1287
- acids (sulfinic) from SO_2 , 1288-1289
- acids (thiocarboxylic) from COS , 1288
- alcohols:
 - by oxid'n of alkyl G. r's., 1264-1273
 - from carbonyl comp'ds, 145-146, 240-309, 310-452, 453-528
 - from carboxylic esters, 549, 557-560, 579-580, 581-586, 591-674
 - from epoxides, 976-977, 978-1012
 - from trimethylene oxide, 1031-1032
- alcohols (cyclic) from cyclic ketones, 146, 453-528
- alcohols (primary) from formaldehyde and $(\text{HCHO})_x$, 145, 240-245
- alcohols (secondary) from:
 - aldehydes, 145-146, 249-309
 - formates, 549, 558, 578-580, 581-586
- alcohols (tertiary) from:
 - carbonates, 561, 580-581
 - carbon dioxide, 913
 - carbonyl sulfide, 1288
 - carboxylic anhydrides, 846-847
 - chloroformates, 560, 579
 - esters, 549, 557-560, 591-674
 - ketones (acyclic), 146, 310-452
 - ketones (cyclic), 146, 453-528
 - nitriles, 772-773
- aldehydes from:
 - formamides, 870
 - formates, 561, 582-586
 - orthoformates, 561, 586-591
- alkylmagnesium chlorides, 26
- allylic Grignard reagents, 17, 18, 24, 27, 28, 47-48
- allylmagnesium chloride, 27
- amines (*t*-alkyl) from nitriles, 772-773
- amines from amides, 871-872
- amines (prim.) from alkoxyamines, 1236-1237
- amines (sec.) from aldimines, 1204-1208
- anilides from phenyl isocyanate, 1199-1204
- anilines (*N,N*-disubst.) from phenyl isocyanate, 1200
- 9-anthrylmagnesium bromide, 29

Preparation of: (*cont'd*)

- azo comp'ds from nitroso comp'ds, 1228-1229
- butenylmagnesium halides, 24, 47-48
- carboxylic esters from:
 - carbonates, 560, 580-581
 - chloroformates, 560, 579
- cinnamylmagnesium chloride, 28
- cyclanols from cyclic ketones, 146, 453-528
- cyclohexylmagnesium chloride, 28
- diorganomagnesium comp'ds, 1, 90-91, 106-107
- dithiocarboxylic acids from CS_2 , 1286-1287
- ethanols from ethylene oxide, 967-977, 978-987
- etheral MgBr_2 , 33
- ethers from acetals, 1041-1045
- ethylmagnesium chloride, 26
- Grignard reagents, 4, 5-91
 - activators and inhibitors in, 8-15
 - agitation of reaction mixture in, 19
 - apparatus for (classical), 22
 - apparatus for (cyclic reactor), 23
 - apparatus for (mech. activation), 7
 - by classical methods, 22-32
 - by entrainment, 38-45
 - by Grignardization of RX , 5-56
 - by hydrogen displacement, 66-86
 - by olefin add'n of RMgX , 87-90
 - by reaction of R^\bullet with $\cdot\text{MgX}$, 86-87
 - by reaction of RHgX with $\text{R}'\text{MgX}'$, 90
 - by reaction of RLi with MgX_2 , 90
 - by reaction of R_2SO_4 with Mg , 90-91
- copper-magnesium alloy in, 12
- from acetylenic hydrocarbons, 66-70
- from alkyl sulfates, 90-91
- from aromatic ethers, 74
- from carbazole, 86
- from dihalides (*gem*), 32
- from dihalides (non-vicinal), 34
- from dihalides (*vic*), 33
- from fluorides, 38
- from free radicals, 86-87
- from hydrocarbons (non-acetylenic), 71-75
- from imidazole, 84-85
- from 2-methylbenzothiazoles, 74
- from nitrogen heterocycles, 75-86
- from olefins, 87-90
- from organolithium comp'ds, 90
- from organomercuri comp'ds, 90
- from pyrazole, 85-86

Preparation of: (*cont'd*)Grignard reagents (*cont'd*)

- from pyrroles, 75-80
- from thiophene, 75
- from vinyl halides, 37
- general method for, 25
- halides for, 25
- in ethers other than Et_2O , 45
- in halide (excess) as solvent, 53-56
- inhibitors in, 13-15
- in hydrocarbons, 50-53
- in solvents other than Et_2O , 45-52
- in tertiary amines, 49
- iodine-activated Mg alloy in, 12
- iodine-activated Mg in, 8, 9
- limitations of classical methods, 32
- quality of Et_2O in, 16
- quality of Mg in, 6, 24
- (quasi) by enolate form'n, 73, 180, 194, 348, 729
- (quasi) from phenylacetic acids, 72
- (quasi) from sulfones, 73
- rate of halide add'n in, 18
- reagents for, 24
- relative reactivities of halides in, 20
- halohydrins from α -halo ketones, 182
- hydrazo comp'ds from azo comp'ds, 1249-1251
- hydrazones from diazo comp'ds, 1223-1226
- hydroperoxides by oxid'n of G. r's., 1266-1267
- hydroxylamines from nitroso comp'ds, 1228
- imides from amides, 872-873
- iodine-activated Mg, 8, 9
- iodine-activated Mg alloy, 12
- ketimines from nitriles, 767, 770-771
- keto acids from carboxylic anhydrides, 847, 849, 851
- ketones from:
 - amides, 870
 - carbon dioxide, 913-914, 917, 918, 919, 920
 - carbonyl halides, 712-724
 - carboxylic anhydrides, 846-847, 851
 - carboxylic esters, 561-562
 - nitriles, 767, 769-772
- magnesium bromide (ethereal), 33
- mesitylmagnesium bromide, 29
- β -methallylmagnesium chloride, 28
- methylmagnesium chloride, 25

Preparation of: (*cont'd*)

- nitriles from amides, 870-871
 - organomagnesium halides, 4, 5-91 (*see* Grignard reagents)
 - ortho esters from orthocarbonates, 561, 581
 - 9-phenanthrylmagnesium bromide, 29
 - phenols by oxid'n of aryl G. r's., 1264-1273
 - phenylmagnesium bromide, 28
 - phthalides from anhydrides, 848, 851
 - styrylmagnesium bromide, 29
 - sulfides from:
 - sulfenates, 1285
 - sulfoxides, 1296
 - thiolsulfonates, 1286
 - sulfinic acids from SO_2 , 1288-1289
 - sulfones from sulfyl halides, 1290-1294
 - sulfonyl halides from sulfuryl chloride, 1294-1295
 - sulfoxides from:
 - sulfinates, 1285
 - sulfinic acids, 1290
 - sulfites, 1285
 - thionyl chloride, 1294
 - thiocarboxylic acids from COS, 1288
 - thioepoxides from thioketones (thiones), 1299
 - thiols by sulfurization of G. r's., 1275
 - triarylsulfonium bromides from sulfoxides (diaryi), 1296-1297
 - triazenes from azides, 1226-1227
 - triphenylmethylmagnesium bromide, 31
- Preparative methods:
- alcohols:
 - from carbonyl compounds, 145-146
 - from carboxylic esters, 557-560
 - demethylation of methoxy groups, 1029-1030
 - dichlorodiethylsilane from SiCl_4 , 1308
 - diorganomagnesium comp'ds:
 - by dioxane precipitation, 106-107
 - by reaction of R_2SO_4 with Mg, 90-91
 - ethanols from ethylene oxide, 976-977
 - ethereal MgBr_2 , 33
 - ethyltrichlorosilane from SiCl_4 , 1308
 - fluorotri-*n*-amylsilane from SiF_4 , 1308
 - Grignard reagents:
 - classical, 22-32
 - entrainment, 38-45
 - general, 25
 - Grignardization of RX, 22-32

Preparative methods: (*cont'd*)Grignard reagents: (*cont'd*)

hydrogen displacement, 66-86

olefin add'n of RMgX , 87-90reaction of R^\cdot with $\cdot\text{MgX}$, 86-87reaction of RHgX with $\text{R MgX}'$, 90reaction of RLi with MgX_2 , 90reaction of R_2SO_4 with Mg , 90-91hexaethylidisiloxane from $\text{Si}(\text{OC}_2\text{H}_5)_4$, 1309

ketimines from nitriles, 770-771

keto acids from carboxylic anhydrides, 851

ketones:

from carbonyl halides, 712-724

from carboxylic anhydrides, 851

from nitriles, 769-772

phthalides from anhydrides, 851

primary alcohols from HCHO or $(\text{HCHO})_x$, 145secondary alcohols from RCHO , 145-146

tertiary alcohols from ketones, 146

tetraethylsilane from SiCl_4 , 1308tetraphenylsilane from SiCl_4 , 1308-1309triethylsilane from HSiCl_3 , 1309

Primary alcohols—prep'n of:

from ethylene oxide, 961-965, 976-977, 978-987

from formaldehyde and $(\text{HCHO})_x$, 145, 240-245

Primary amines:

as "active" H comp'ds, 141

from alkoxyamines, 1236-1237

Pseudohalogen:

cyano group as, 776-778

phenoxy group as, 35, 1013

Pulegone—enolization of (T. VI-VI), 168

Purification of solvents for Grignard reactions, 24

Purity:

of halide in G. r. prep'n, 16

of magnesium in G. r. prep'n, 6

Pyrazolyl Grignard reagents, 85-86

Pyridine as precipitant for MgX_2 and RMgX , 106

Pyrrolenines—tautomerism with pyrroles, 75

Pyrroles:

as sources of G. r's., 75-78

constitution of G. r's. from, 75-77

tautomerism with pyrrolenines, 75

Zerewitinoff analysis of, 76

Pyrrol Grignard reagents, 75-80

constitution of, 75-77

Pyrrol ions—resonance of, 76-77

Quasi Grignard reagents:

enolates as, 73, 180, 194, 348, 729

phenylacetic acids as sources of, 72

sulfones as sources of, 73, 1297-1299

Quasi six-membered ring transition state in:

1,2-add'n to conj. carbonyl systems, 223-224

1,4-add'n to conj. carbonyl systems, 221-223

1,4-add'n to conj. epoxides, 976

alkoxide-carbonyl red'n, 160

alkyl dihalide dehalogen'ns, 1053

alkyl halide dehydrohalogen'ns, 1052
allylic halide and allylic G. r. reactions, 1050

butenyl G. r. reactions, 1155

enoliz'n of ketones, 176

epoxide reactions, 964-965

ether cleavage, 1024-1025

G. r.-allylic halide reactions, 1157-1158

G. r.-carbonyl add'n, 142

G. r.-carbonyl red'n, 154, 156, 157

"normal" alkyl halide reactions, 1049

ortho condens'ns of benzyl G. r's., 1142-1145reductive enoliz'n of α -halo ketones, 195-196

Quaternary salts—reactions with G. r's., 1251-1255

Quinolines—reactions with G. r's., 51, 1257-1258

Quinones:

as bifunctional conj. carbonyl systems, 529

reactions with G. r's. (T. VII-II), 535-548

Radical reactions of G. r's., 116-137

Radicals—attack of on solvents:

in G. r. electrolyses, 112

in Grignardization, 63

in metallic halide reactions, 124

Radicals—dimerization of:

acyl, 126-127

as source of Wurtz product, 63, 64

 α -cumyl, 124

induced by metallic halides, 118, 124-125, 1056-1059

in G. r.-aralkyl halide reactions, 1054-1056

in G. r. electrolyses, 112

in Grignardization, 62, 63, 64

- Radicals—disproportionation of, 6, 59, 63, 64, 112, 116, 118, 124–125, 151
- Radicals (free):
behavior in sol'n, 124–126
Grignard reagents from, 86–87
reductive ether cleavage by, 1025–1029
- Radicals—relative electronegativities of, 20, 113, 124, 153, 225, 227, 970–972
- Rate of enolization of camphor (T. VI–IV), 167
- Rate of halide add'n in G. r. prep'n, 18–19
- Reactions induced by cobaltous halides, 122–131
- Reactions of Grignard reagents (*see* Grignard reagents—reactions with)
- Reactions of Group IB halides, 118–119, 133–135
- Reactions of Group VIII (Fe, Co, Ni) halides, 119–122, 135–136
- Reactivities (relative) of:
carboxylic esters toward G. r's., 554–557
G. r's. toward ketones, 140, 142, 227
G. r's. toward nitriles, 142, 768
halides in G. r. prep'n, 20
ketones toward G. r's., 225, 1174
nitriles toward G. r's., 142, 767–768
organometallic comp'ds toward benzalacetophenone, 226
- Reagents for G. r. prep'n, 24
- Rearrangements:
allylic in Grignard reactions, 1133–1165
Beckmann-type in oxime reactions, 1218–1221
of epoxides, 965–967, 968–973
analogy with hydrobenzoin, 968ff.
of free radicals, 125–126
of halohydrates, 183–189
analogy with pinacol-pinacolone, 187–188
epoxide-intermediate, 189
pinacol-pinacolone type of halohydrates, 183–188
stereospecificity in, 972–973
Walden inversion in epoxide, 972
- Reducing tendencies (relative) of G. r's. toward CO groups, 153
- Reduction (asymmetric):
of carbonyl groups by alkoxides, 160
of pinacolin by (+)-CH₃(C₂H₅)–CHCH₂MgCl, 155
- Reduction (asymmetric): (*cont'd*)
of unsym. ketones by asym. G. r's., 154–157
- Reduction of:
aldehydes and ketones by:
alkoxides, 158–160
Grignard reagents, 147–157, 218–219
magnesium halides, 160–166
benzophenone by RMgX (T. VI–II), 153
carbonyl groups by alkoxides, 158–160
asymmetric, 160
mechanism of, 160
carbonyl groups by G. r's., 147–166
asymmetric, 154–157
mechanism of, 154, 156
suppression of, 157–158
carbonyl halides by G. r's., 725–727
carboxylic esters, 562–563
ketones and aldehydes by:
alkoxides, 158–160
Grignard reagents, 147–157, 218–219
magnesium halides, 160–166
ketones by metallic subhalides, 127–128, 160–166
thioketones (thiones) by magnesium halides, 1299
- Reduction (Meerwein):
of carbonyl groups, 158–160
- Reductive displacement of:
CN from RCN, 779–782
X from α -halo amides, 873–874
X from α -halo ketones, 189–196
X from α -halo nitriles, 784–785
- Reductive enolization of:
 α -halo carboxylates, 950
 α -halo ketones, 189–196
mechanism of, 193–196
- Relative electronegativities of organic radicals, 20, 113, 124, 153, 225, 227, 970–972
- Relative migratory aptitudes of groups, 970–972
- Relative reactivities of:
carboxylic esters toward G. r's., 554–557
G. r's. toward ketones, 140, 142, 227
G. r's. toward nitriles, 142, 768
halides in G. r. prep'n, 20
ketones toward G. r's., 225, 1174
nitriles toward G. r's., 142, 767–768
organometallic comp'ds toward benzalacetophenone, 226
- Relative reducing tendencies of G. r's. toward CO groups, 153

Resonance of:

- benzyl ions, 1141
- butenyl ions, 1156
- enolate ions, 194
- phenolate ions, 1140-1141
- pyrryl ions, 76-77
- triarylmethyl carbonium ions, 1051-1052

Ring-opening of epoxides (direction of):

- factors influencing, 967-975
- in additions, 973-975
- in isomerizations, 968-973

Rubber as inhibitor in G. r. prep'n, 14

Schlenk equilibrium, 68, 104-109

Secondary alcohols from aldehydes, 145-146, 245-309

Secondary amines from aldimines, 1204-1208

Selenium comp'ds—reactions with G. r's., 1302-1303

Selenium—reactions with G. r's., 1274-1276

Semicarbazones—reactions with G. r's., 1222-1223

Silicon compounds—reactions with G. r's., 1306-1331

silicon esters, 1307, 1322-1331

silicon halides, 1306-1307, 1310-1331

Silver halides—reactions with G. r's., 119, 133-134

Six-membered ring transition state (quasi) in:

1,2-add'n to conj. carbonyl systems, 223-224

1,4-add'n to conj. carbonyl systems, 221-223

1,4-add'n to conj. epoxides, 976

alkoxide-carbonyl red'n, 160

alkyl dihalide dehalogen'ns, 1053

alkyl halide dehydrohalogen'ns, 1052

allylic halide and allylic G. r. reactions, 1050

butenyl G. r. reactions, 1155

enoliz'n of ketones, 176

epoxide reactions, 964-965

ether cleavage, 1024-1025

G. r.-allylic halide reactions, 1157-1158

G. r.-carbonyl add'n, 142

G. r.-carbonyl red'n, 154, 156, 157

"normal" alkyl halide reactions, 1049

ortho condens'ns of benzyl G. r's., 1142-1145reductive enoliz'n of α -halo ketones, 195-196Solubility of MgBr_2 in Et_2O and G. r. sol'ns, 44

Solvent association with G. r's., 99-102

Solvents—attack of radicals on:

in G. r. electrolyses, 112

in Grignardization, 63

in metallic halide reactions, 124

Solvents (other than Et_2O) in G. r. prep'n, 45-52

Solvents—purific'n for Grignard reactions, 24

Stereospecificity in:

G. r.-halohydrin reactions, 1065

rearrangements, 972-973

Steric influences in:

G. r.-carbonyl add'n, 170

G. r.-carboxylic ester reactions, 555-557

G. r. enoliz'n of ketones, 170

G. r.-epoxide reactions, 973-975

triarylmethyl halide reactions, 1051-1052

Sulfates (alkyl):

as sources of G. r's., 90-91

reactions with G. r's., 1277-1278, 1278-1281

Sulfenates—reactions with G. r's., 1285

Sulfide form'n in thionyl chloride reactions, 1294

Sulfides (organic) as "catalysts" in G. r. prep'n, 51

Sulfides—prep'n from:

sulfenates, 1285

sulfoxides, 1296

thiolsulfonates, 1286

Sulfonates—reactions with G. r's., 1285

Sulfinic acids:

prep'n from SO_2 , 1288-1289

reactions with G. r's., 1290

Sulfites—reactions with G. r's., 1285

Sulfone form'n in sulfonic ester reactions, 1284

Sulfones:

as active H comp'ds, 1171

as sources of G. r's. (quasi), 73

prep'n from sulfonyl halides, 1290-1294

reactions with G. r's., 1297-1299

Sulfonic esters—reactions with G. r's., 1278, 1281-1285

Sulfonium halides from sulfoxides, 1296-1297

Sulfonyl halides:

prep'n from sulfonyl chloride, 1294-1295

reactions with G. r's., 1290-1294

- Sulfoxide form'n in sulfonyl halide reactions, 1290-1294
- Sulfoxides—prep'n from:
 sulfinates, 1285
 sulfinic acids, 1290
 sulfites, 1285
 thionyl chloride, 1294
- Sulfoxides—reactions with G. r's., 1296-1297
- Sulfur chlorides—reactions with G. r's., 1295
- Sulfur comp'ds as inhibitors in G. r. prep'n, 14
- Sulfur comp'ds (unclass.)—reactions with G. r's., 1300-1302
- Sulfur dioxide—reactions with G. r's., 1288-1290
- Sulfur—reactions with G. r's., 1274-1276
- Sulfuryl chloride—reactions with G. r's., 1294-1295
- Suppression of G. r.-carbonyl red'n, 157-158
- Tautomerism of pyrroles with pyrrolenines, 75
- Tellurium comp'ds—reactions with G. r's., 1303-1305
- Tellurium—reactions with G. r's., 1276
- Tertiary alcohols—prep'n from:
 carbonates, 561, 580-581
 carbon dioxide, 913
 carbonyl sulfide, 1288
 carboxylic anhydrides, 846-847
 chloroformates, 560, 579
 esters, 549, 557-560, 591-674
 ketones (acyclic), 146, 310-452
 ketones (cyclic), 146, 453-528
 nitriles, 772-773
- Tertiary amines as:
 "catalysts" in G. r. prep'n, 50-53
 complex-formers with G. r's., 142, 156
 solvents in G. r. prep'n, 49
- Thiocarboxylates—reactions with G. r's., 1286
- Thiocarboxylic acids from carbonyl sulfide, 1288
- Thioepoxides from thioketones (thiones), 1299
- Thio ethers as "catalysts" in G. r. prep'n, 51
- Thioketones (thiones)—reactions with:
 Grignard reagents, 1299
 magnesium halides, 1299
- Thiols by sulfurization of G. r's., 1275
- Thiolsulfonates—reactions with G. r's., 1286
- Thionyl chloride—reactions with G. r's., 1294
- Thiophthene as source of G. r., 75
- Tichtchenko reaction, 181
- Transition state (quasi six-membered ring) in:
 1,2-add'n to conj. carbonyl systems, 223-224
 1,4-add'n to conj. carbonyl systems, 221-223
 1,4-add'n to conj. epoxides, 976
 alkoxide-carbonyl red'n, 160
 alkyl dihalide dehalogen'ns, 1053
 alkyl halide dehydrohalogen'ns, 1052
 allylic halide and allylic G. r. reactions, 1050
 butenyl G. r. reactions, 1155
 enoliz'n of ketones, 176
 epoxide reactions, 964-965
 ether cleavage, 1024-1025
 G. r.-allylic halide reactions, 1157-1158
 G. r.-carbonyl add'n, 142
 G. r.-carbonyl red'n, 154, 156, 157
 "normal" alkyl halide reactions, 1049
 ortho condens'ns of benzyl G. r's., 1142-1145
 reductive enoliz'n of α -halo ketones, 195-196
- Triarylsulfonium bromides from sulfoxides (diaryl), 1296-1297
- Triazines:
 prep'n from azides, 1226-1227
 tautomerism of, 1226
- Tribenzylphosphine oxide as "catalyst" in G. r. prep'n, 51
- Triethylsulfonium iodide as "catalyst" in G. r. prep'n, 53
- Trimethylene oxide as source of alcohols, 1031-1032
- Tritium as tracer in *ortho* condens'n of benzyl G. r., 1142-1143
- Tschugaeff-Zerewitinoff method for det'n of active H, 1166-1198
 applications, 1173-1174
 "Grignard machine," 1169
 limitations, sources of error, 1171-1173
- Unstable intermediate organometallic comp'ds, 118-119
- Unsym. ketones—asym. red'n by asym. G. r's., 154-157
- Vinyl alcohols:
 from enolate hydrolyses, 222, 238-239
 from G. r.-ketone red'ns, 239

Vinyl halides in G. r. prep'n, 37

Wagner-Saytzeff synthesis, 3

Walden inversion in:

allylic halide reactions, 1050-1051

epoxide rearrangements, 972

ether cleavage, 1024

sulfonic ester reactions, 1278

Water in G. r. prep'n, 14

Werner complexes of G. r. components
with:

t-amines, 142, 156

carbonyl comp'ds, 138-142, 223,
1141

ethers, 99-102, 106, 156, 1023

ketimines, 1209

nitriles, 142, 767-769

Wurtz product:

from G. r. prep'n in benzene, 52

in Grignardization, 15, 52, 63, 152,
1046

Wurtz reaction, 6, 39, 59, 63, 152

Wurtz reaction (internal), 33

Yields of alcohols:

primary from HCHO and (HCHO)_x,
145

Yields of alcohols: (*cont'd*)

secondary from RCHO, 145-146

tertiary from acyclic ketones, 146

tertiary from cyclic ketones, 146

Yields of Grignard reagents—effect of:

Cu-Mg alloy, 13

Et₂O-dil'n of halide, 17

halide-add'n rate, 19

halide halogen, 32

Yields of Grignard reagents prep'd in:

benzene, 52

n-butyl ether, 47

classical manner, 30

hydrocarbon solvents, 53

4-methyl-1,3-dioxane, 49

Yields of "normal" products from G.
r's. prep'd by entrainment, 41-
42

Zerewitinoff analysis of pyrrole, 76

Zerewitinoff method for det'n of "ac-
tive" H, 1166-1198

applications, 1173-1174

"Grignard machine," 1169

limitations, sources of error, 1171-
1173

Zinc and cadmium salts in ketone
prep'n, 713-724